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## AUTOMATED LONGWALL GUIDANCE AND CONTROL SYSTEMS PHASE II, PART I: VERTICAL CONTROL SYSTEM (VCS)

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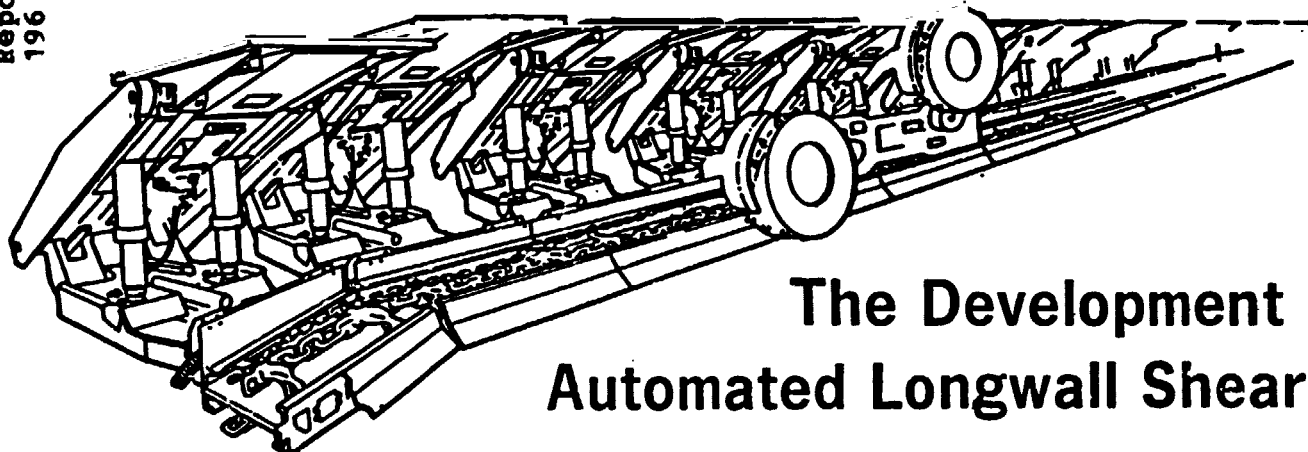
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**George C. Marshall Space Flight Center, Alabama 35812**

**April 5, 1979**

**For the U. S. Department of Energy**



# The Development of Automated Longwall Shearer

**George C. Marshall Space Flight Center**  
Marshall Space Flight Center, Alabama 35812

Prepared for  
U. S. Department of Energy  
and  
National Aeronautics Administration

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THE  
BENDIX  
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ENERGY, ENVIRONMENT  
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FINAL REPORT

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GUIDANCE AND CONTROL  
SYSTEMS

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PHASE II, PART I  
VERTICAL CONTROL  
SYSTEM (VCS)

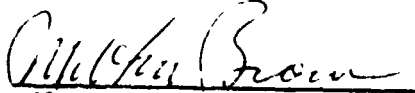
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#### FOREWORD

This report is submitted in accordance with the requirements of Contract No. NAS8-32921, Data Requirement (DR), MA04A, Phase II Final Report, Part I - VCS.

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## 1.0 INTRODUCTION

Dwindling domestic and world oil and gas supplies with the inevitable rise in the price of these fuels have generated deep concern within government, industry, and the general public as to how the energy needs of the country can reasonably and economically be met in the future. The increased use of coal, our most abundant fossil fuel reserve, during the next quarter century will necessitate increasing the efficiency of underground coal extraction. Longwall mining techniques have the potential of greatly increasing the coal yield per acre and coal production per man per shift since it is essentially a continuous mining process. In addition, since longwall is a continuous mining process employing continuous haulage, it is extremely well suited for automation which is the subject of the present study. Automating longwall coal extraction will not only increase production but also minimize the amount of foreign material taken along with the coal thus reducing sorting time and cutter bit wear. In addition, automating or remotizing the longwall mining process will increase operator health and safety by removing the miner from the shearer and thus the hazards encountered in the immediate cutting area.

The present study has been divided into two phases. Phase I was primarily concerned with the analyses and simulation of candidate Vertical Control Systems (VCS) and Face Advancement Systems (FAS) (consisting of a Yaw Alignment System and Roll Control System) required to satisfactorily automate the longwall system. The purpose of these studies were to specify the desired overall longwall system configuration for preliminary design which will be performed during Phase II of the study. A report outlining the analyses and simulations performed during Phase I of the study which led to a specification of the overall longwall system was issued in September 1978. This report outlines the prototype preliminary design of the Vertical Control System (VCS) portion of the Automated Longwall Guidance and Control System specified at end of Phase I.



## 2.0 SUMMARY

The Automated Longwall Guidance and Control System consists of a Vertical Control System (VCS) for controlling the elevation of the two cutting drums of a double ended ranging arm longwall shearer; a Yaw Alignment System (YAS) for maintaining the longwall face straight and perpendicular to both the headgate and tailgate; a Roll Control System for maintaining proper shearer attitude about its longitudinal axis; and a Master Control Station (MCS) from which the shearer can be operated automatically, or if desired, remotely. The paragraphs that follow will summarize the prototype preliminary design of the VCS portion of the Automated Longwall Guidance and Control System. The longwall shearer used in the preliminary design specified is the JOY LLS1-300 double ranging arm shearer. It should also be noted that since the VCS is one element in the overall automated longwall system, the design of the VCS did take into account the other subsystem requirements. Where convenient the electronics were designed and sized to accept roll control and yaw alignment sensing signals as described in Section 4.0.

2.1 VCS Operational Modes - The Automated Longwall System and hence the VCS will have the following operational modes:

- a. Automatic Mode
- b. Remote Mode
- c. Manual Mode

Each of these modes are described below.

2.1.1 VCS Automatic Mode - The automatic mode is the normal mode for VCS operation. In this mode the VCS is capable of automatically controlling the elevation of both cutting drums of the double ended ranging arm shearer for traverse velocities of up to fifty feet per minute with the nominal traverse being thirty feet per minute. The shearer turn around will be manually assisted by personnel located in the headgate and tailgate who will be in voice communication with the operator at the Master Control Station. When the observers indicate to the MCS operator that everything is clear of debris, the MCS operator will initiate the shearer turn around sequence. If there is debris on the shearer at the end of the pass which could jam the deployments required at turn around, the observers in the headgate or tailgate depending on where shearer turn around is taking place, will clear the debris. Once clear the observer will tell the MCS operator to initiate the turn around sequence. This procedure significantly simplifies the VCS design by eliminating the requirement for automatic debris sensing equipment (possibly a video system) from being mounted on the shearer. It should be noted that even if a

video system were mounted on the shearer if debris would be present that might prevent shearer turn around, personnel would still be required to clear the shearer. This would mean that when the shearer is in the tailgate, the longwall system would have to be shut down and personnel sent down the length of the longwall face to clear the shearer and come back, introducing significant delays in mining operations.

2.1.2 VCS Remote Mode - The remote operational mode for the VCS will primarily be used for system checkout and troubleshooting. There will not be a remote full-up operational mode that will be used to operate the longwall system while mining coal. The reason for this is twofold:

a) It is highly improbable that an operator at the master control station could digest the sensor information required for control of (i.e., Last Cut Follower, Sensitized Pick, CID, Present Cut Follower, etc.) the shearer cutting drums and react properly so as to affect satisfactory control. This consideration does not include monitoring the roll sensors and maintaining proper shearer attitude about its longitudinal axis.

b) Since all of the sensor information will be obtained from the processor so as to allow single line digital communication between the shearer and the remote control station, it is difficult to postulate a mode of failure that the remote mode could accommodate. In order to control the shearer remotely all of the sensors would have to be operable, the communication system with the processor would have to be operable, the I/O into the processor would have to be operable, and at least a portion of the processor would have to be operable in order to properly process CID and sensitized pick data. This does not leave very much that could reasonably fail and yet allow the required portions of the system to be operable in order to enable the remote operation of the shearer.

However, the remote mode in conjunction with manual assist as described above will be used for shearer turn around.

2.1.3 VCS Manual Mode - The manual mode of operation provides for the shearer to be operated by personnel located in the vicinity of and moving along with the shearer as is presently done. The VCS hardware is designed to in no way interfere with the present manual mode of shearer operation. Therefore should a malfunction occur coal could still be mined as is presently done until the next maintenance shift when the VCS could be repaired.

**2.2 Safety Considerations** - System safety was a prime consideration in the design of the VCS. Various features were included in the design of the VCS to insure the safety of personnel operating the system. Included in these features are the following.

1. Keys are located on the first and last (i.e., near headgate and tailgate respectively) roof supports. The number of keys in these roof supports are equal to the number of men normally located on a shift. When a person is required to be along the longwall face for whatever reason, the operating procedure calls for him to turn any of the locks located in the first or last roof support releasing the key and taking it along with him. This disables operation of the automated longwall system including the VCS in automatic or remote modes. Only when the key is replaced and the lock turned can the longwall system be operated automatically or remotely. Assuming that this procedure is followed it would preclude personnel located along the longwall face from being injured by inadvertent turn on of the automated longwall system. It should be noted that essentially the same safety procedure is presently being used by the power industry in order to avoid circuit breaker turn on while maintenance personnel are located along the power line.

2. When the shearer is being operated manually a switch located on the shearer is thrown which disables automatic or remote operation of the automated longwall system including the VCS. The only way that automatic/remote operation could be restored is if the switch on the shearer is manually thrown to its nominal position. This feature is a backup to the keys described above and enables the manual shearer operators to walk out of the longwall face area safely if the "key" procedure described above is adhered to.

3. When using an Active Nucleonic CID various sensing devices are furnished in order to detect a possible radiation hazard. These include the following:

a. A pressure sensor which monitors the pressure in the chamber where the nucleonic source is located. The chamber is initially pressurized and when the pressure drops below a certain value a structural failure is assumed to have occurred, the system is shutdown and an audible alarm located on the shearer is sounded.

b. A sensor that monitors the position of the aperture covers of the nucleonic source. When an indication is received that the source aperture cover is not in its proper position for a particular mode of operation, the system is shutdown and an audible alarm located on the shearer is sounded.

c. A radiation detector is mounted on the shearer which detects the general background radiation levels. Should this detector sense radiation levels appreciably above normal, the system is shut-down and an audible alarm located on the shearer is sounded.

It should be noted that the radiation hazard indicators including the audible alarm will be operational even if power is completely removed from the shearer, requiring a separate battery pack to power the radiation hazard warning system when shearer power isn't present. This would keep maintenance personnel operating on the shearer with power turned off apprised of any radiation hazard that may exist.

2.3 VCS Performance with the Passive Radiation and Active Nucleonic CID's - Studies were conducted to establish the cutting performance that could be achieved using the passive radiation and active nucleonic CID's. Ten successive passes were made with the longwall shearer with each of the CID's determining such parameters as RMS cut error, percent time in rock, and percent rock taken. However, before making the successive passes to determine cutting performance, studies were required to determine the optimum averaging interval for each of the CID's. These studies resulted in optimum averaging intervals of 0.5 and 2.0 seconds for the active nucleonic and passive radiation CID's respectively. Using these averaging intervals, the cutting performance achieved with both CID types is summarized in Table 2-1. It is seen from these tables that the performance of the Active Nucleonic CID is somewhat better than the Passive Radiation CID. However the performance with the passive radiation CID is considerably better than that presently being achieved manually at shearer traverse velocities of up to 50 ft/min, far in excess of the manual traverse velocity of ten to twelve feet per minute. Hence VCS performance with the natural radiation sensor meets the VCS system requirement that cutting performance be equal to what is presently being manually achieved.

Referring to Table 2-1 it is noted that both the top and bottom drum spend approximately the same percent of time in rock yet essentially no rock is taken from the roof while a small percentage rock is taken from the floor. The reason for this apparent discrepancy is that the top drum has sensitized picks which it reacts to, allowing it to just graze the coal/shale interface and essentially taking no coal. However, the floor drum is controlled by slaving it to the top drum so as to maintain constant seam height. The sensitized pick data on the bottom drum is used for display only and not for its active control. The reason for not actively responding to sensitized pick data is to maintain the difference between two successive cuts on the floor within defined limits. This can only be accomplished by maintaining constant seam height since it is not feasible to mount a last cut follower on the floor. Therefore, although the time in rock for the floor cutting drum is approximately the same as the roof appreciably more rock is taken on the floor since the cutting drum will penetrate the coal/shale interface.

Table 2-1. VCS Performance Summary

	AVERAGE RMS ROOF CUT ERROR (IN)	AVERAGE RMS FLOOR CUT ERROR (IN)	AVERAGE RMS CUT ERROR (IN)
AUTOMATED VERTICAL CONTROL NUCLEONIC CID	2.32	3.19	2.76
AUTOMATED VERTICAL CONTROL NATURAL RADIATION CID 5 IN. CRYSTAL	2.74	3.54	3.14
*MANUALLY OPERATED VERTICAL CONTROL SYSTEM	N/A	N/A	**5.5

\*AVERAGE OF ALL MEASURED PERFORMANCE  
12 FACES IN 10 DIFFERENT MINES  
A.D. LITTLE SURVEY (DEC. 1976-JUNE 1977)

\*\*3.1 IN. MEAN ERROR

4 IN. BIAS  
ROBINSON RUN MINE

SHEARER VELOCITY = 30 FT/MIN  
RESULTS ESSENTIALLY UNCHANGED AT 50 FT/MIN

Table 2-1. VCS Performance Summary (Concluded)

	AVERAGE PERCENT TIME IN ROCK ROOF (%)	AVERAGE PERCENT TIME IN ROCK FLOOR (%)	AVERAGE ROCK TAKEN ROOF (%)	AVERAGE ROCK TAKEN FLOOR (%)
AUTOMATED VERTICAL CONTROL NUCLEONIC CID	8.73	7.03	0	0.11
AUTOMATED VERTICAL CONTROL NATURAL RADIATION CID 5 IN. CRYSTAL	11.28	14.43	0	0.18

ACTIVE NUCLEONIC CID

AVERAGE PERCENT TIME IN ROCK - 7.88%  
 AVERAGE PERCENT ROCK TAKEN - 0.11%

PASSIVE RADIATION CID

AVERAGE PERCENT TIME IN ROCK - 12.86%  
 AVERAGE PERCENT ROCK TAKEN - 0.18%

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The recommended VCS configuration is the one employing the passive radiation CID. Although the active nucleonic sensor yields better VCS cutting performance, the safety considerations involved with the active radiation source make it difficult to obtain the permits necessary to allow its underground use. However the VCS design will be compatible with both the passive radiation and active nucleonic CIDs allowing both sensors to be used interchangeably with simple adapting hardware (see Section 5). When the required permits are obtained for the active nucleonic CID it will be taken underground, tested, and compared to the passive radiation sensor. Should the comparison prove favorable it could displace the passive radiation CID for VCS cutting drum control.

**2.4 VCS Electronic Design** - The heart of the electronics for the automated longwall system and hence the VCS is the Electronic Control Module (ECM). The ECM accepts signals from all of the shearer mounted sensors, operates on them and drives the appropriate control elements (actuators) to achieve satisfactory automated system operation. The major electronic blocks comprising the ECM are signal conditioning, communication subsystem, Input/Output (I/O), and Central Processing Unit (CPU). An overall block diagram of the major blocks comprising the ECM and the interfaces between them and the rest of the automated longwall system elements is shown in Figure 2-1.

Due to the large electrical motors on the shearer (i.e., drum cutter motors, shearer haulage motor) face conveyor, stage loader, and panel conveyor the potential for electromagnetic interference is high. Therefore digital electronics and sensors were used wherever possible in order to minimize the effects of E&M interference. Once this choice was made it was necessary to establish whether the digital sensor signals should be brought directly to the ECM via cabling maximizing the number of lines in the cables employed, or to use multiplexing techniques that would reduce the number of lines going to the ECM. Two types of multiplexing techniques were considered. One was to use serial digital multiplexing across a single pair of wires and the other was to employ parallel digital multiplexing where the number of wires would be determined by the largest digital word to be transmitted. Examination of these options indicated that although the number of lines contained in the cabling was reduced by these two multiplexing techniques they could not be eliminated. This is due to the necessity of powering the various sensors from the power distribution center located in the ECM. Therefore, the result of the trade study performed indicated that the electronic complication and cost introduced by multiplexing and the loss of flexibility in the manner data could be transmitted to the ECM outweighed the savings that could be realized by eliminating some lines in cables that had to be there anyway. Therefore the digital sensor data is brought directly to the ECM without employing any multiplexing techniques.

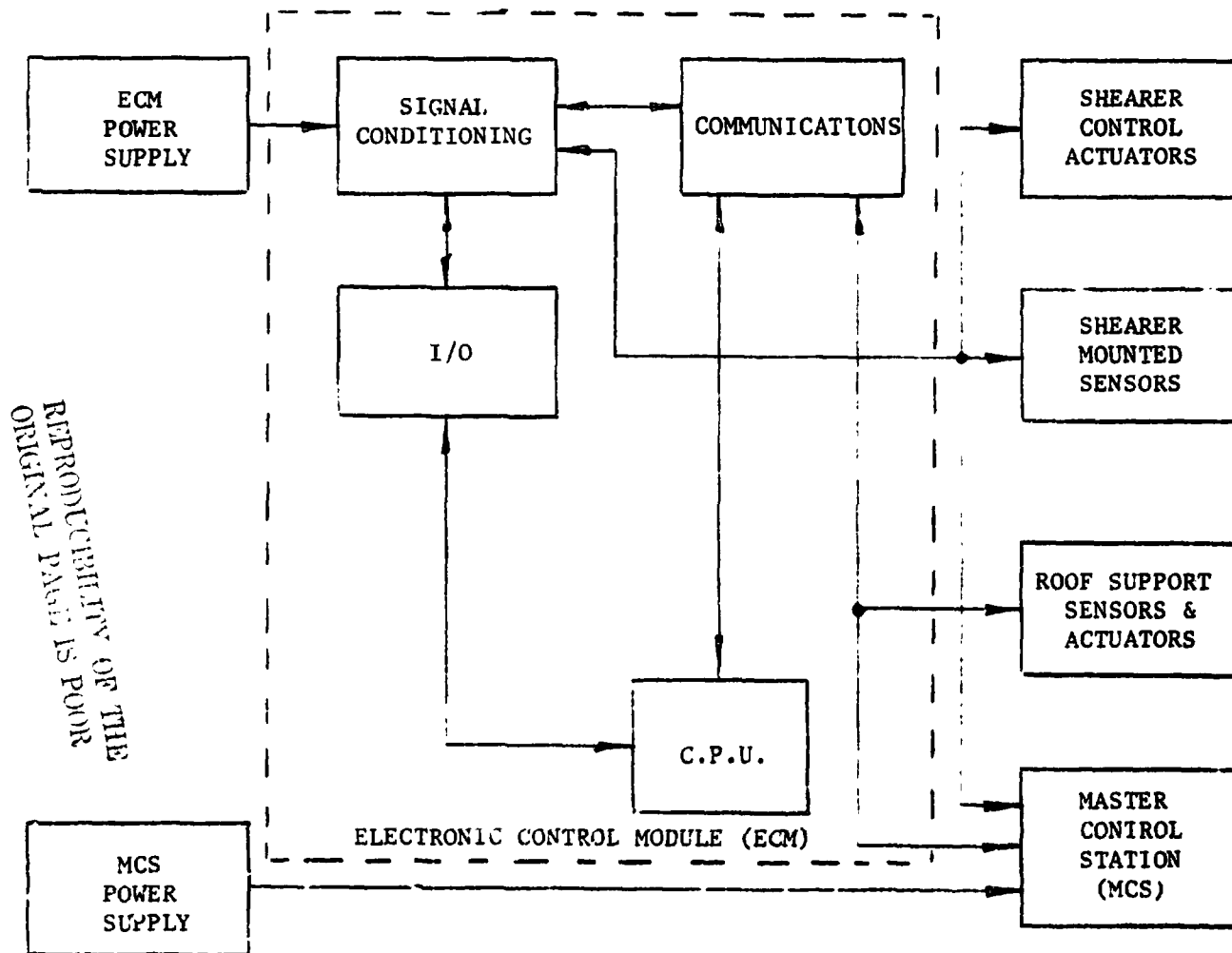


Figure 2-1. Electronic Design of Automated Longwall System



The next major trade to be made was whether to use a minicomputer or a microprocessor for computation and control law implementation. Top level flow diagrams showing the required control law algorithms, housekeeping and status monitoring algorithms, were generated in order to size the storage capacity and computational power required. This resulted in a system size that could be handled in a very flexible and cost effective manner by present day microprocessor technology. In addition since it is desired that the ECM be intrinsically safe a minicomputer would probably not allow that design goal to be met. Therefore a microprocessor based system was decided upon for the electronic design of the ECM. The device family selected employs CMOS technology wherever possible to further reduce power requirements and obtain high noise immunity.

The above design decisions has resulted in an intrinsically safe ECM. It should be noted however, that some elements contained in the signal conditioning block, particularly the high voltage drivers required for solenoid operation, will be housed in the ECM explosion proof power supply housing.

As described above (Section 2.2) safety was a prime consideration in the electronic design of the VCS. In addition to the precautions outlined in Section 2.2. the status of the various sensors mounted on the shearer are continually monitored. Should there be an indication that current/voltage levels are exceeding nominal limits a warning is flashed to the MCS operator. If the voltage/current limits exceed maximum allowable limits, power is removed from the affected sensor and system operation is interrupted. Similarly the voltage and current levels in the motors for the face conveyor, stage loader, and panel conveyor are continuously monitored. Should there be an indication that one of these conveyors have stopped or the current is exceeding allowable limits the shearer is halted in order to avoid coal spillage. In addition the manual controls on the shearer is safety interlocked with VCS electronics allowing the automatic/remote modes of operation only if the manual controls are in their proper (i.e., off) positions.

Algorithms are also incorporated to determine whether a particular measurement obtained from a sensor is reasonable. If the sensor measurement is considered unreasonable then the last value of the measurement is employed. Should a particular signal fail to pass the reasonable test criteria a warning is flashed to the MCS operator.

The electronic design of the VCS assumed that an active nucleonic CID was employed for shearer drum control although this is not the recommended CID. The reason for this approach was the desire to make the electronics accommodate both the passive radiation and active nucleonic CIDs. The active nucleonic CID has a more complex electronic implementation, particularly with regard to the requirement

for radiation hazard monitoring, and the additional encoding needed for the two independent suspensions. Therefore the electronic design that resulted can readily accommodate the passive radiation CID by eliminating those functions peculiar to the active nucleonic sensor. Had the electronics been designed to accommodate the passive radiation CID significant hardware/software modifications would be required if the active nucleonic CID was then to be accommodated.

**2.5 VCS Mechanical Design** - The mechanical design of the VCS that has evolved suspends the CID and present and last cut followers from a parallelogram type mechanism which follows the ranging arm through most of its travel (i.e., within 5 degrees from horizontal). The CID is mounted approximately four feet behind the cutting drum for a 54" drum diameter and maintains this distance constant throughout the design travel of the parallelogram mechanism.

The present and last cut following mechanisms are combined into one cut follower, and depending on shearer direction of motion, will index to follow the last or present cut. The measurement of cut height in either case is with respect to the drum centerline i.e., the height of the cut directly above the drum center of rotation. This measurement is accomplished by an arm of a given length in contact with the roof, the contact surface being a shoe or ball, and measuring the angle the arm makes with respect to a horizontal member on the mounting platform (see Section 5.0). The cut following arm is in such a position that when an obstruction or void is encountered the follower will be knocked out of the way without being damaged. Hydraulic damping is provided so that the arm doesn't snap back too fast and possibly incur some damage.

The parallelogram mechanism is capable of accommodating both the active nucleonic and passive radiation CIDs by simple adjustments and adaption hardware. The active nucleonic CID is loaded against the roof with enough pressure to minimize air gaps. However, if an obstruction is encountered the CID will swing out of the way (and the aperture covers will snap shut) without incurring any damage. Hydraulic damping is provided so that the CID will not spring back too quickly once the obstruction is passed.

The passive radiation CID is also loaded against the roof primarily to achieve self cleaning (If coal accumulates on the measuring surface of the passive radiation CID a measurement error results). The sliding surface will be made of spring steel approximately one sixteenth of an inch thick above the detection crystal thus introducing a minimum amount of attenuation to the incoming natural radiation. Since air gaps are of no consequence for the passive radiation CID the preload pressure is appreciably less than that required for the active nucleonic CID. Therefore the wear would not be severe and the sliding steel surface would last a reasonable length of time.

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The mechanical design for the VCS is compatible with all the drum sizes manufactured for the Joy LLS1-300 shearer which range from 42 to 62 inches regardless of CID being employed. The design will operate in seam heights of 62.8 inches and above for both CIDs being considered.

Another design feature of the mechanical system is that all mechanisms will be locked in place should a hydraulic failure occur. This will prevent the collapse of CID and cut follower suspensions, and the mounting platform, which could possibly result in instrument and mechanism damage. The CID's, cut followers, deployment/stowage mechanisms can be stowed manually by loosening the proper hydraulic fittings.

### 3. VCS PERFORMANCE STUDIES

The following paragraphs will describe the mathematical sensor models used, and the VCS performance characteristics achieved using passive radiation, and active nucleonic Coal Interface Detectors (CID). In this evaluation of cutting performance a Joy 300-1LS1 longwall shearer with a 54 in. diameter drum was assumed. For this machine and cutting drum diameter the CID (regardless of type) is mounted approximately four feet behind the cutting drum (see Section 5).

**3.1 Active Nucleonic CID Mathematical Model** - The calibration curve for a 20 in. (i.e., 20 in. separation between source and detector) CID sensor is shown in Figure 3-1. There is a cesium 137 source emitting gamma radiation, which is backscattered by the coal. Therefore, the thicker the coal, the more backscatter. Thus, the number of counts per second increase with the coal depth. Two basic sources of error are modeled for this sensor: a variation in the number of counts received in a given interval, and the effect of air gap.

The curve in Figure 3-1 illustrates the relation between coal depth and the number of counts acquired in 8 sec. The counts represent the average number of counts received in this interval. The number of events occurring in a given interval is Poisson distributed, with density function

$$f(\lambda) = \frac{(\lambda\tau)^i e^{-\lambda\tau}}{i!} \quad i = 0, 1, 2, \dots$$

where  $\lambda$  is the parameter of the distribution - in this case, the average number of counts per unit time. For a given time interval  $\tau$  the mean and variance of the Poisson distribution are

$$\mu = \lambda\tau$$

$$\sigma^2 = \lambda\tau$$

thus, as the interval  $\tau$  is reduced, the average number of counts decreases as well as the variance. The measurements become noisier, however, because the ratio of standard deviation to mean becomes larger as  $\tau$  decreases.

The air gap error occurs whenever the source or detector is not in complete contact with the coal surface. In this case, radiation short-circuits the coal and is picked up by the sensor directly, thereby resulting in a larger number of counts than would normally be expected for a given depth of coal. When the calibration curve shown in Figure 3-1 is used to interpret this data, the coal depth indicated by the sensor is larger than that actually present.

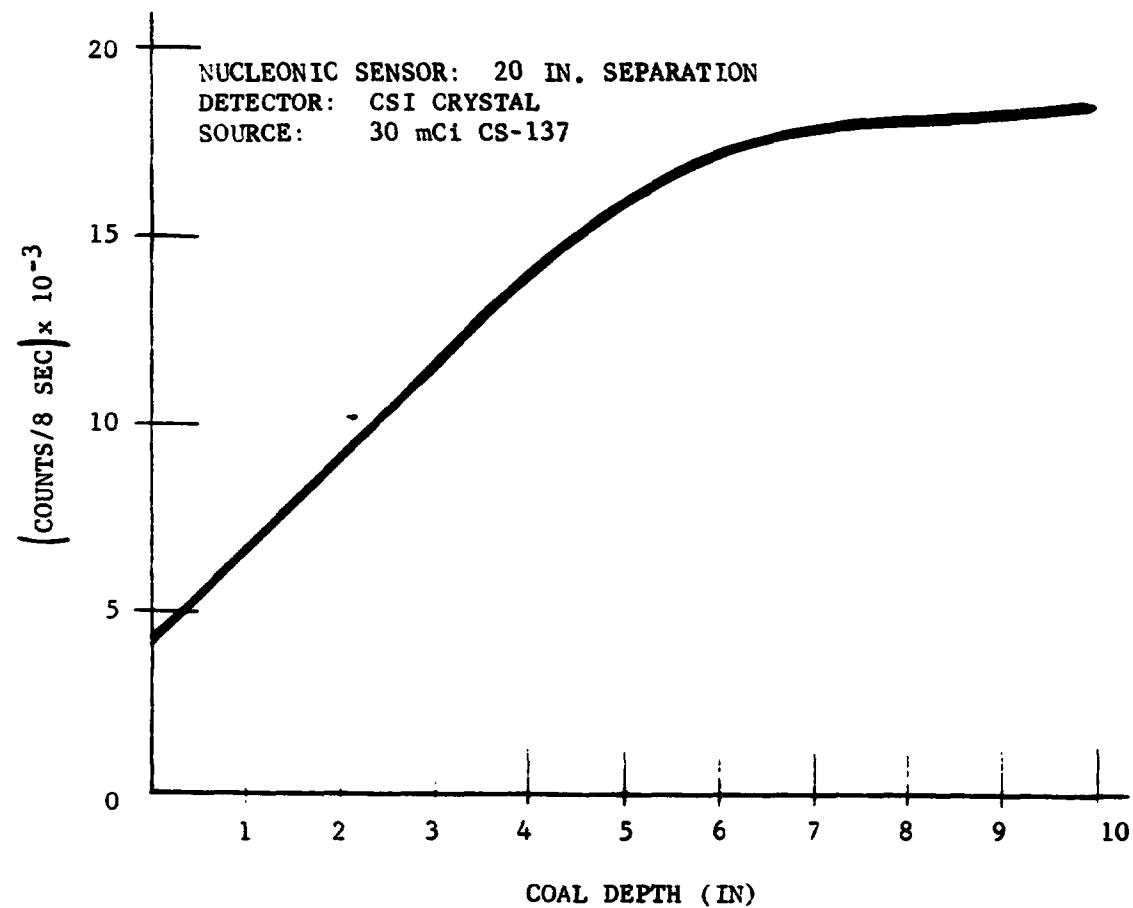


Figure 3-1. Nucleonic CID Calibration Curve

The simulation of this sensor was as follows:

(1) Coal depth is computed every 0.05 sec. and averaged for  $\tau$  seconds which simulates the averaging due to motion of the CID during the interval  $\tau$  as the shearer traverses the face.

$$n = \tau / 0.05$$

$$\epsilon_A = \frac{1}{n} \sum_{i=1}^n \epsilon_i$$

(2) Calibration curve  $f_{\text{CAL}}(x)$  is used to determine the number of counts/second for  $\epsilon_A$  inches of coal

$$C = f_{\text{CAL}}(\epsilon_A) / 8$$

$$C_{\text{ACT}} = C\tau$$

(3) Poisson distributed noise is added to  $C_{\text{ACT}}$  with mean and variance of  $C\tau$

$$C_N = C_{\text{ACT}} + P(C\tau)$$

(4) Uniformly distributed noise between the interval (0 - 250) counts/second is added to simulate an air gap of 0 - 0.5 in.

$$C_N = C_N + U(0 - 250)$$

(5) The calibration curve is again used to interpret  $C_N$  as inches of coal

$$\epsilon_N = f_{\text{CAL}}^{-1} \left( \frac{8}{\tau} C_N \right)$$

The resultant value of  $\epsilon_N$  is treated as the CID output, available every  $\tau$  second.

**3.2 Natural Radiation CID Model** - The natural radiation sensor measures background radiation transmitted through the coal, from the

naturally radioactive overburden. Figure 3-2 shows the calibration curve for a 3 in. crystal detector without shielding. Since the radiation is transmitted rather than backscattered, the number of counts decreases as coal depth increases. The number of counts is considerably lower than with the nucleonic sensor and, as a result, the natural radiation sensor is inherently more noisy. Since there is no radiation source, air gaps have little effect on the sensor performance. The simulation is the same as with the active nucleonic sensor, except that the natural radiation calibration curve is used, and air gap noise is omitted. In the simulation of VCS performance a 5 in. detection crystal was assumed. In order to simulate the 5 in. crystal the counts on the calibration curve shown in Figure 3-1 was scaled by the ratio of the square of the crystal diameters i.e.,  $(\frac{5}{3})^2$  or 2.778 to account for the increased number of counts due to the 5 in. diameter.

**3.3 Optimization of CID Averaging Interval** - As indicated above the longer the averaging interval  $\tau$  the smaller the noise error in the CID measurement tending to improve VCS cutting performance. However, as the averaging interval increases the effective lag through the sensor increases tending to degrade VCS cutting performance. Therefore, for a given CID in a particular mounting location behind the cutting drum there exists an averaging interval which will result in optimum VCS cutting performance. This optimum averaging interval was determined for both the passive radiation and active nucleonic CID in their designed mounting location approximately four feet behind the cutting drum. Table 3-1 and 3-2 lists the RMS cut error and the percent time in rock for the passive radiation and active nucleonic CID's respectively as a function of CID averaging time for the condition where the VCS was under CID control only and the bottom drum slaved. In addition the actuator dynamics were eliminated from the simulation since they have no effect on the results and computer running time is decreased. Referring to Tables 3-1 and 3-2 it is seen that the optimum averaging interval is 2.0 and 0.5 sec for the passive radiation and active nucleonic CIDs respectively. These values were used in all of the VCS performance evaluations described below.

**3.4 VCS Performance with Passive Radiation CID** - Using the optimum averaging interval of 2.0 sec for the passive radiation CID VCS cutting performance was determined. Ten consecutive passes were made with the longwall shearer using the VCS control system defined at the conclusion of the phase I portion of the study. This system consists of a passive radiation CID, two sensitized picks having a 90 percent accuracy, and a past cut follower for roof cutting drum control. The bottom cutting drum is slaved to the top drum maintaining a constant seam height by a present cut follower located directly above the center of the bottom drum and bearing on the present cut (See Section 5). The results of these studies are outlined in Table 3-3, and show that the VCS exhibits stable performance as repeated

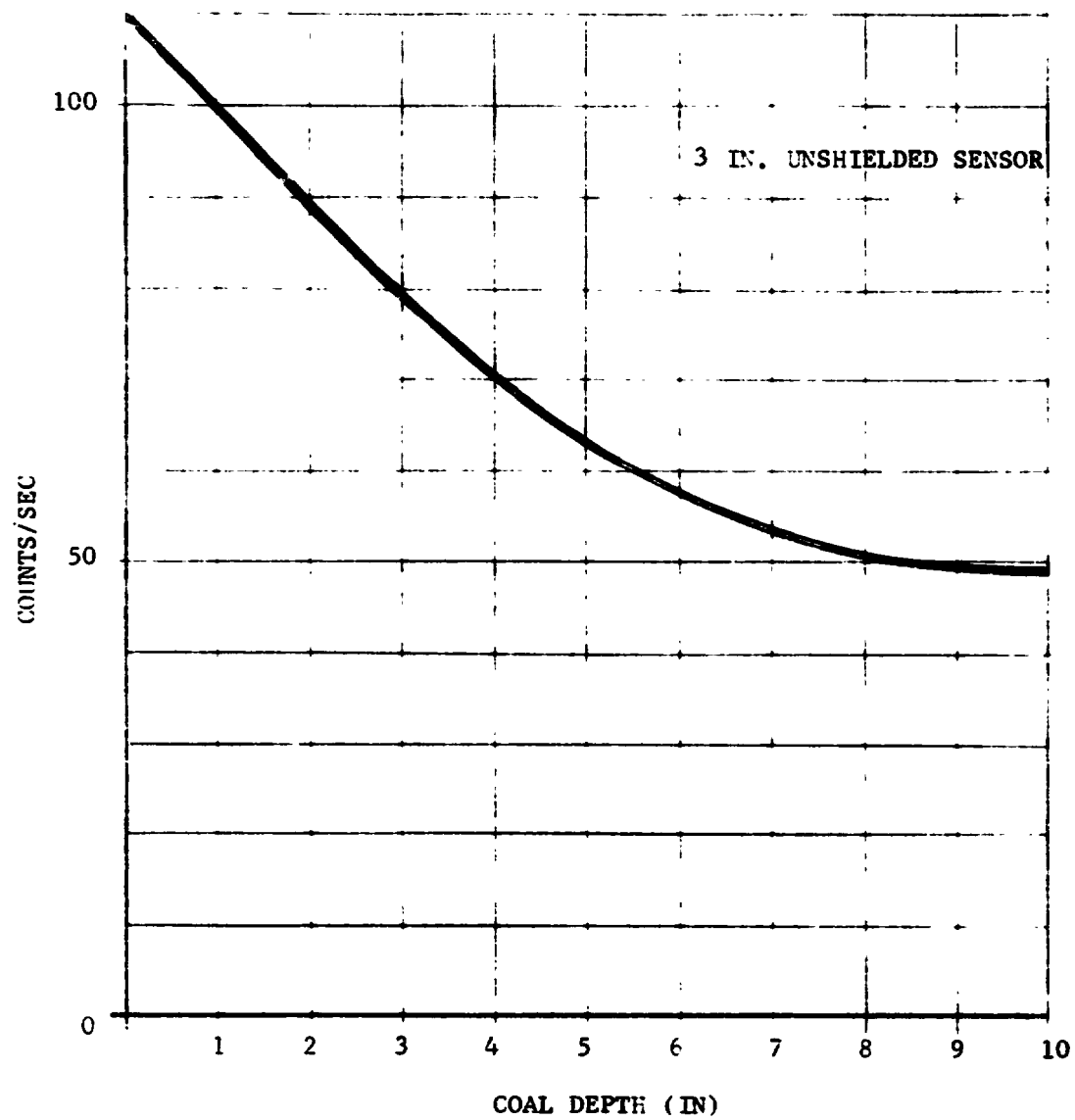


Figure 3-2. Natural Radiation CID Calibration Curve

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**Table 3-1. VCS Performance as a Function of Averaging Interval  
for the Passive Radiation CID**

Averaging Interval (sec)	ROOF		FLOOR	
	RMS Cut Error (in)	Percent Time in Rock (%)	RMS Cut Error (in)	Percent Time in Rock (%)
1	2.92	15.6	3.36	9.75
2	2.71	11.8	3.36	12.7
3	2.9	15.4	3.53	14.29

CID Control Only  
 No Actuator Dynamics  
 Robinson Run Mine  
 CID 4 ft. behind cutting drum  
 Bottom drum slaved  
 4 in. Bias

Table 3-2. VCS Performance as a Function of Averaging Interval  
for the Active Nucleonic CID

Averaging Interval (sec)	ROOF		FLOOR	
	RMS Cut Error (in)	Percent Time in Rock (%)	RMS Cut Error (in)	Percent Time in Rock (%)
0.25	2.51	11.1	3.19	6.12
0.5	2.48	12.02	3.15	5.9
1.0	2.54	11.1	3.2	6.58
2.0	3.05	17.2	3.51	6.35

CID Control Only  
No Actuator Dynamics  
Robinson Run Mine  
CID 4 ft. behind cutting drum  
Bottom drum slaved  
4 in. bias

Table 3-3. VCS Performance Using Passive Radiation CID

Pass No.	ROOF		FLOOR	
	RMS Cut Error (in)	Percent Time in Rock (%)	RMS Cut Error (in)	Percent Time in Rock (%)
1	2.01	0.7	3.08	14.7
2	2.28	3.4	3.38	12.5
3	2.31	4.1	3.11	8.0
4	2.62	10.8	3.35	7.4
5	2.75	14.2	3.14	11.0
6	2.76	9.4	3.43	11.7
7	2.55	6.1	3.41	10.7
8	2.88	13.5	3.81	17.4
9	2.94	17.7	3.86	19.9
10	2.58	6.8	3.58	15.9
Average of Last Five Passes	2.74	11.28	3.54	14.43

Robinson Run Mine  
 With Actuators  
 Sensitized Picks 90% Correct  
 4 in. Bias  
 Passive Radiation CID 4 ft. Behind Cutting Drum  
 2 sec. CID Averaging Interval  
 5" Detection Crystal

cutting passes are made. The average cutting error for a 30 ft/min shearer traverse speed, using the last five passes in order to eliminate the starting transient, was 2.74 in RMS with an 11.28 percent time in rock for the roof, and a 3.54 in RMS with an 14.43 percent time in rock for the floor. This compares favorably with the 5.5 in RMS cut error which includes a mean of 3.1 in presently being obtained manually. It is therefore concluded that the VCS using a passive radiation CID meets overall system performance requirements of equalling or surpassing the performance presently achieved manually at a shearer traverse speed of 30 ft/min. Figure 3-3 shows VCS performance characteristics for the first pass using the passive radiation CID.

3.5 VCS Performance with an Active Nucleonic CID - Replacing the passive radiation CID with the active nucleonic CID keeping all other elements of the control system identical to that described above, VCS performance was determined. The averaging interval used was 0.5 sec. which yielded optimum performance for the active nucleonic CID as described in Section 3.3. Ten consecutive passes with the long-wall shearer were made and the results outlined in Table 3-4 and show that stable VCS performance results when using the active nucleonic CID. The average cutting error for a 30 ft/min shearer traverse speed, using the last five passes to eliminate starting transients, was 3.23 in RMS with an 8.73 percent time in rock for the roof and 3.19 in RMS with an 7.03 percent time in rock for the floor. This exceeds the manual performance of 5.5 in RMS cut error and hence meets overall VCS performance requirements. Figure 3-4 shows VCS performance characteristics for the first pass using the active nucleonic CID.

3.6 Recommended VCS Configuration - The recommended VCS configuration is the one employing the passive radiation CID. Although the active nucleonic sensor yields better VCS cutting performance, the safety considerations involved with the active radiation source make it difficult to obtain the permits necessary to allow its underground use. However the VCS design will be compatible with both the passive radiation and active nucleonic CIDs allowing both sensors to be used interchangeably with simple adapting hardware (See Section 5). When the required permits are obtained for the active nucleonic CID it will be taken underground, tested, and compared to the passive radiation sensor. Should the comparison prove favorable it could displace the passive radiation CID for VCS cutting, drum control.

## PERFORMANCE EVALUATION

## PASS 1

TOTAL COAL TAKEN = 4104.422 CU. FT.

AVERAGE CUT HEIGHT = 7.446 FT.

CUT STANDARD DEVIATION = 0.030 FT.

## FLOOR

RMS ERROR = 3.073 IN.

AVERAGE ABSOLUTE ERROR = 2.530 IN.

VOLUME EXCESS COAL LEFT = 53.215 CU. FT. ( 1.30%)

VOLUME EXCESS COAL TAKEN = 55.544 CU. FT. ( 1.35%)

VOLUME ROCK TAKEN = 7.466 CU. FT. ( 0.18%)

TIME IN ROCK = 14.74%

## ROOF

RMS ERROR = 2.012 IN.

AVERAGE ABSOLUTE ERROR = 1.726 IN.

VOLUME EXCESS COAL LEFT = 34.302 CU. FT. ( 0.84%)

VOLUME EXCESS COAL TAKEN = 44.995 CU. FT. ( 1.10%)

VOLUME ROCK TAKEN = 0.013 CU. FT. ( 0.00%)

TIME IN ROCK = 0.68%

Figure 3-3. VCS Performance Using Passive Radiation CID with 5 in. Crystal (Page 1 of 5)

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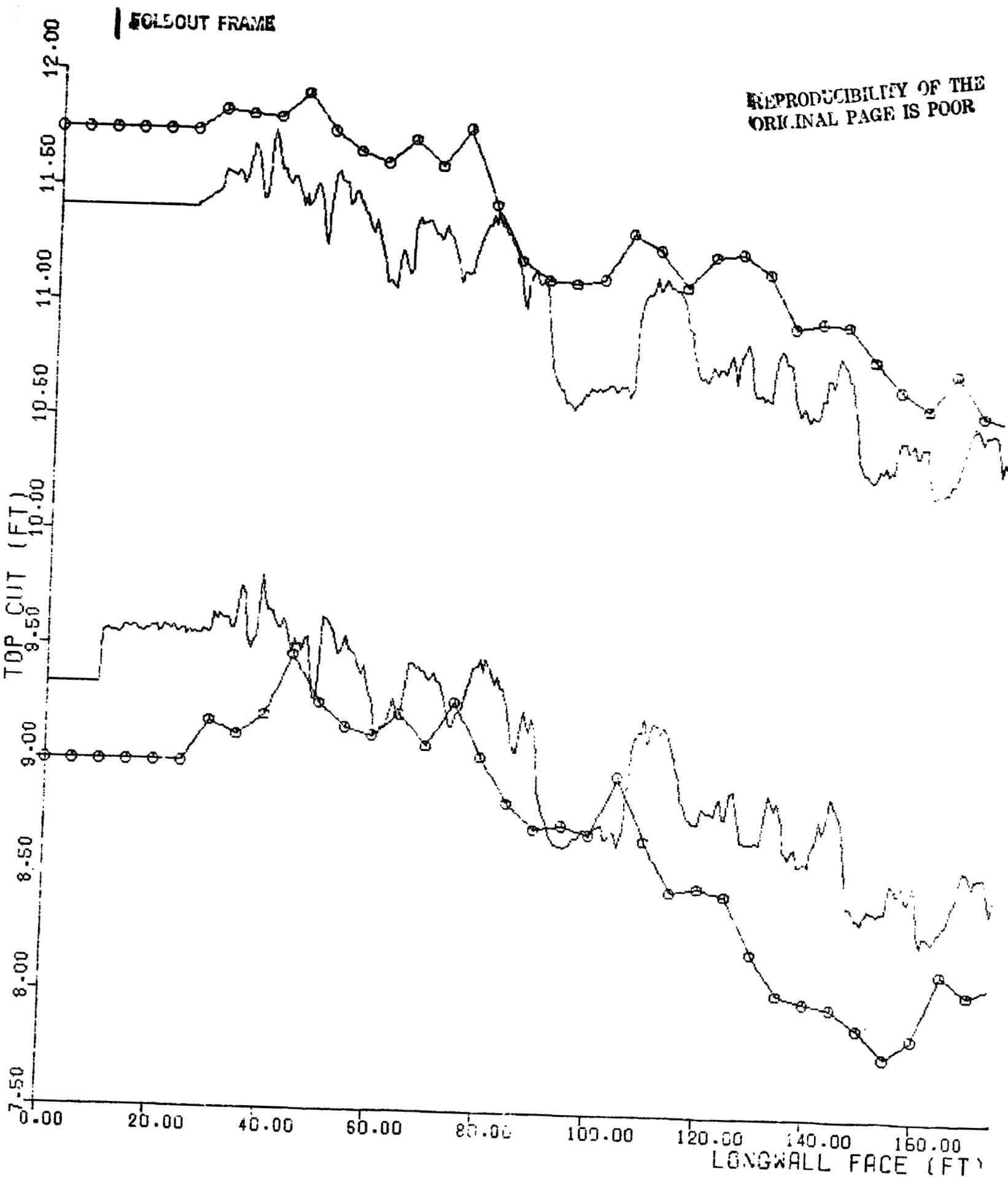
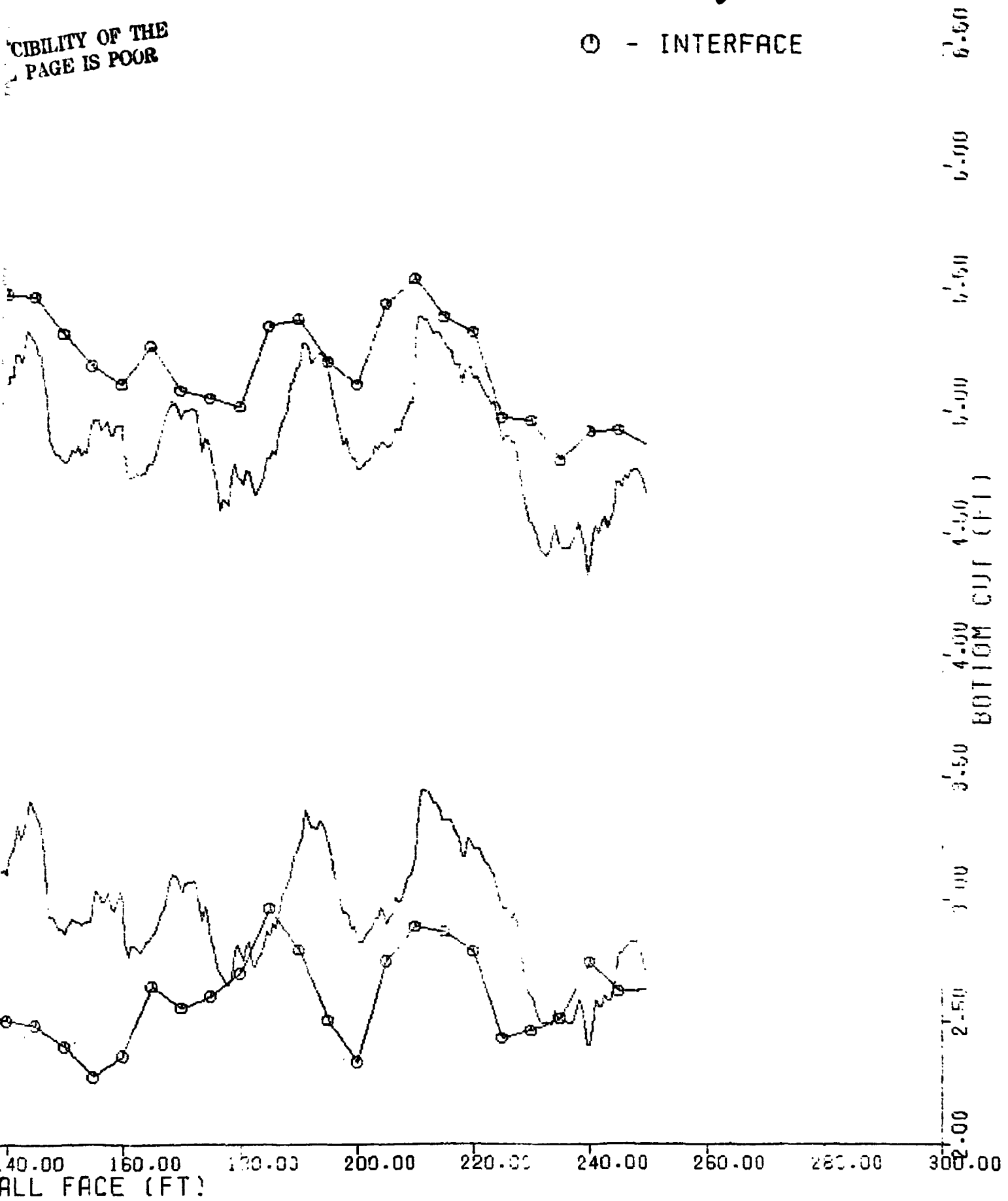


Figure 3-3 VCS Performance Using Passive Radiation C

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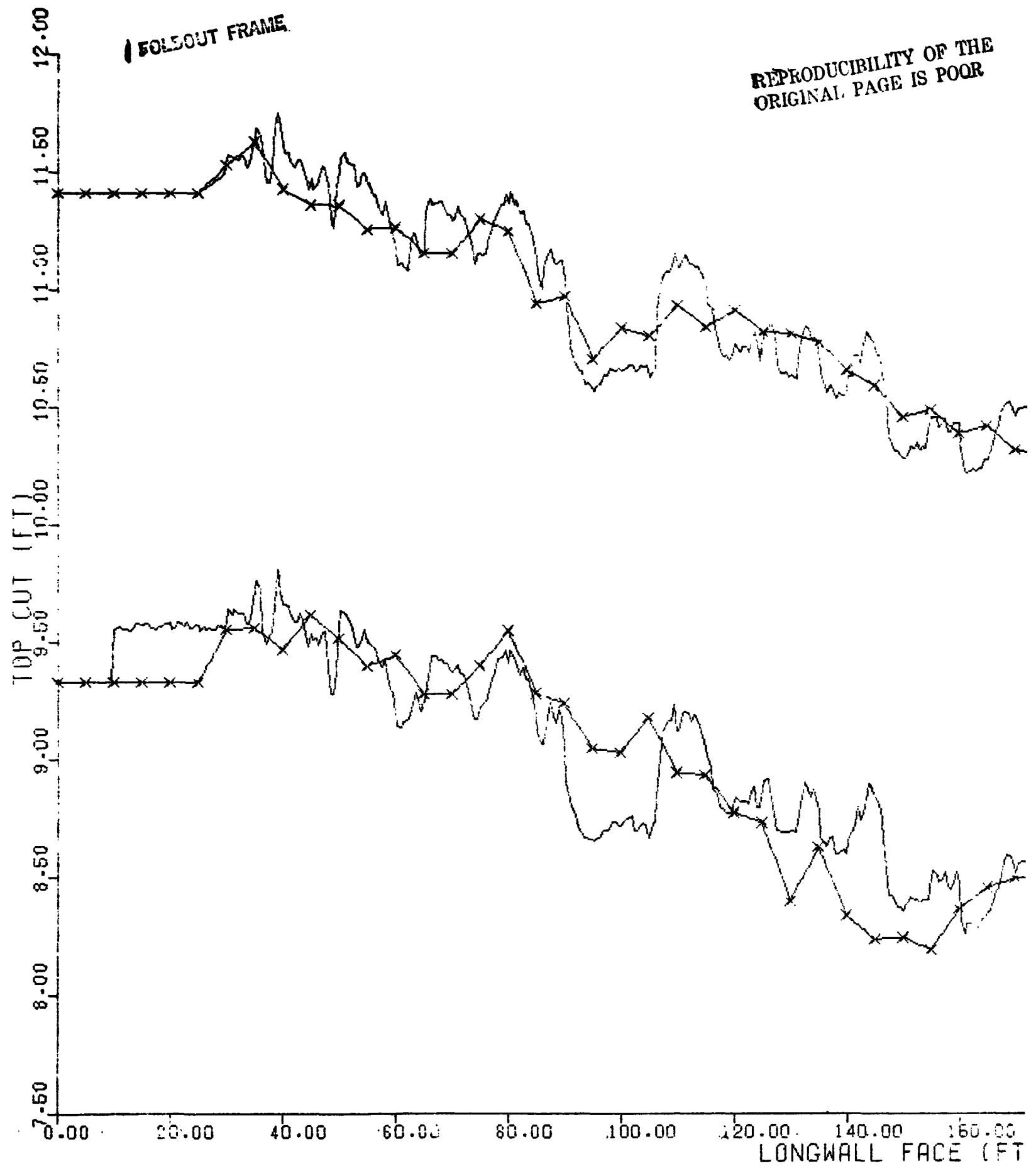


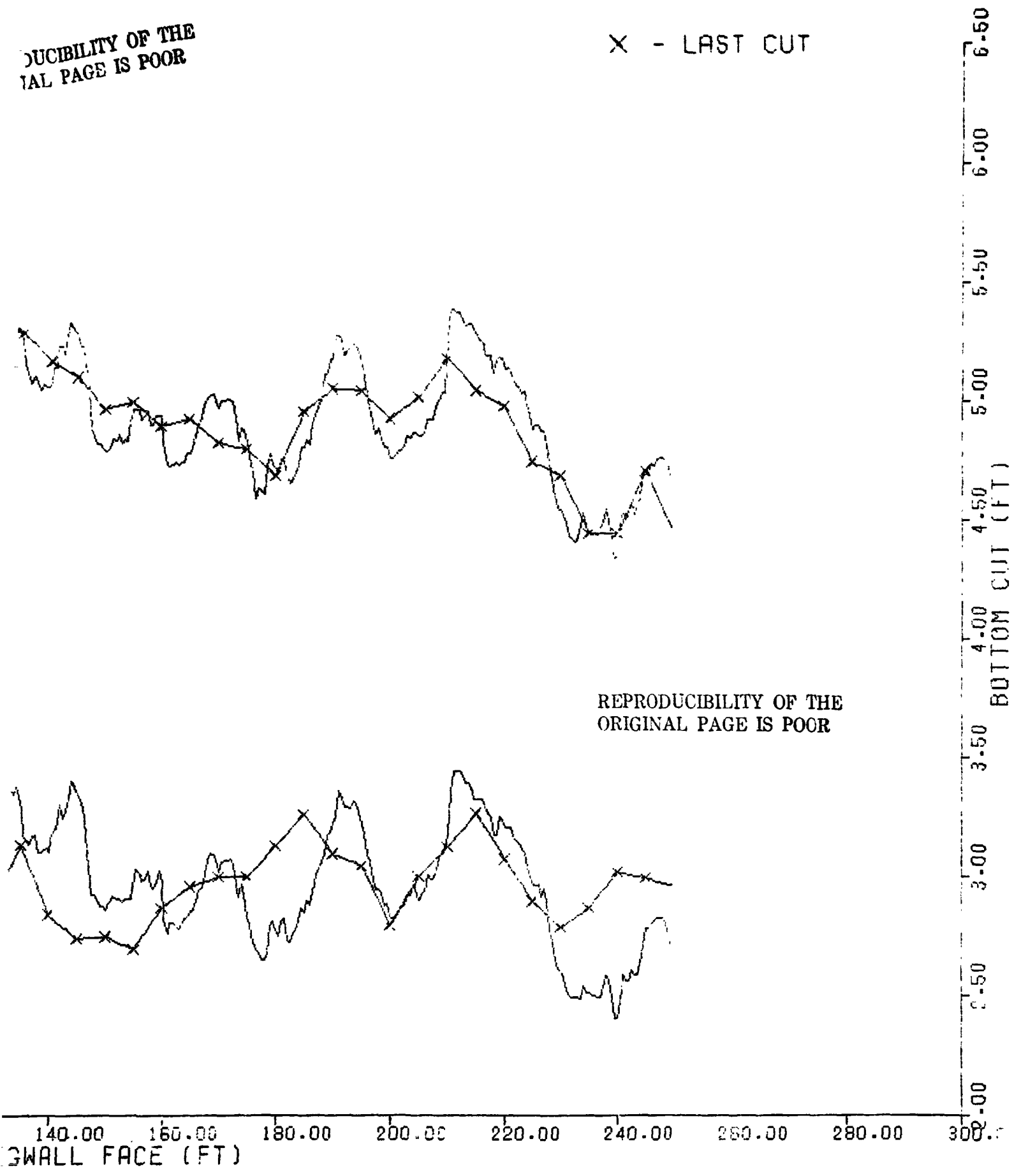
Figure 3-3. VCS Performance Using Passive Radar



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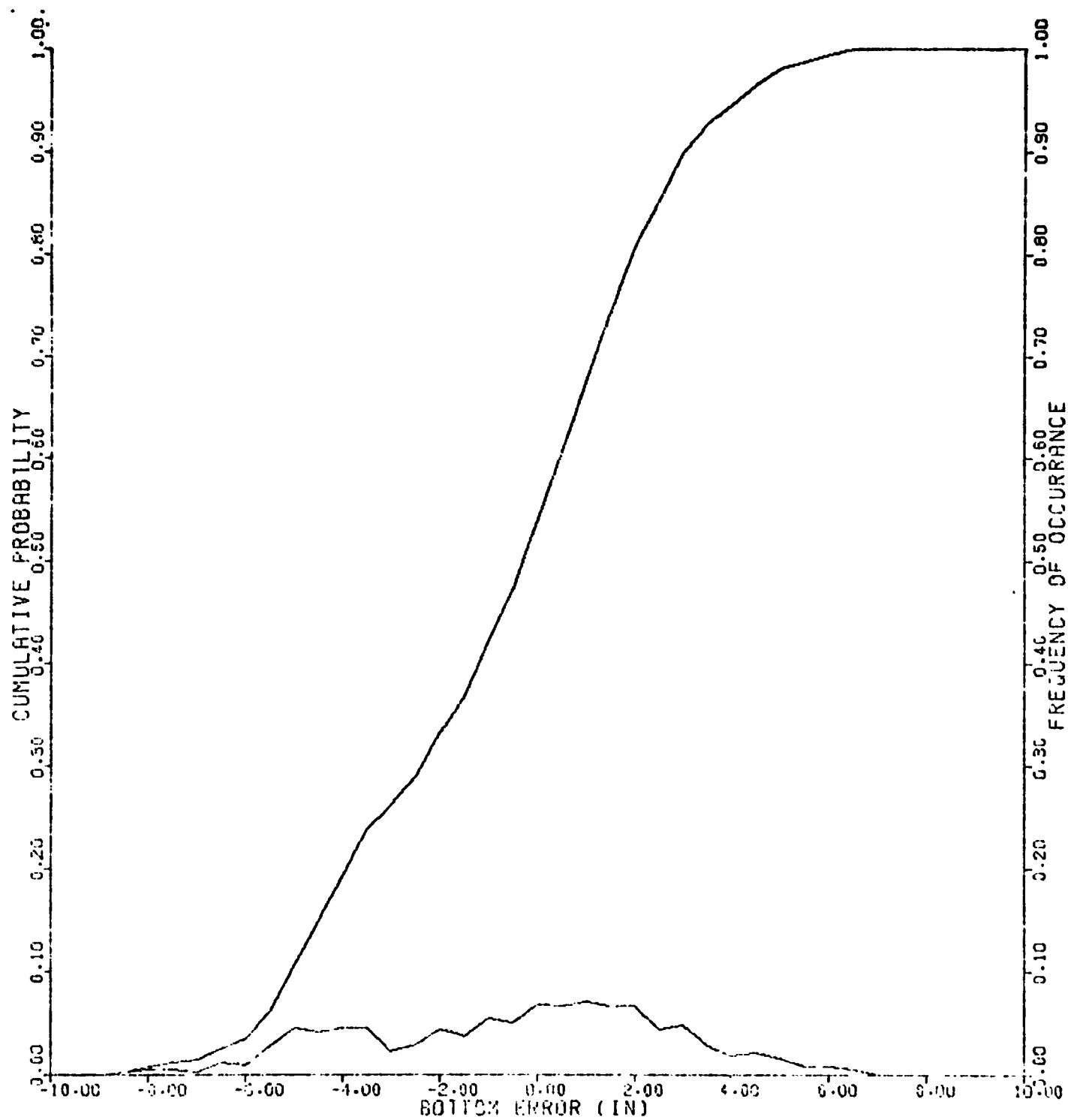


Figure 3-3. VCS Performance Using Passive Radiation CID with 5 in. Crystal (Page 4 of 5)

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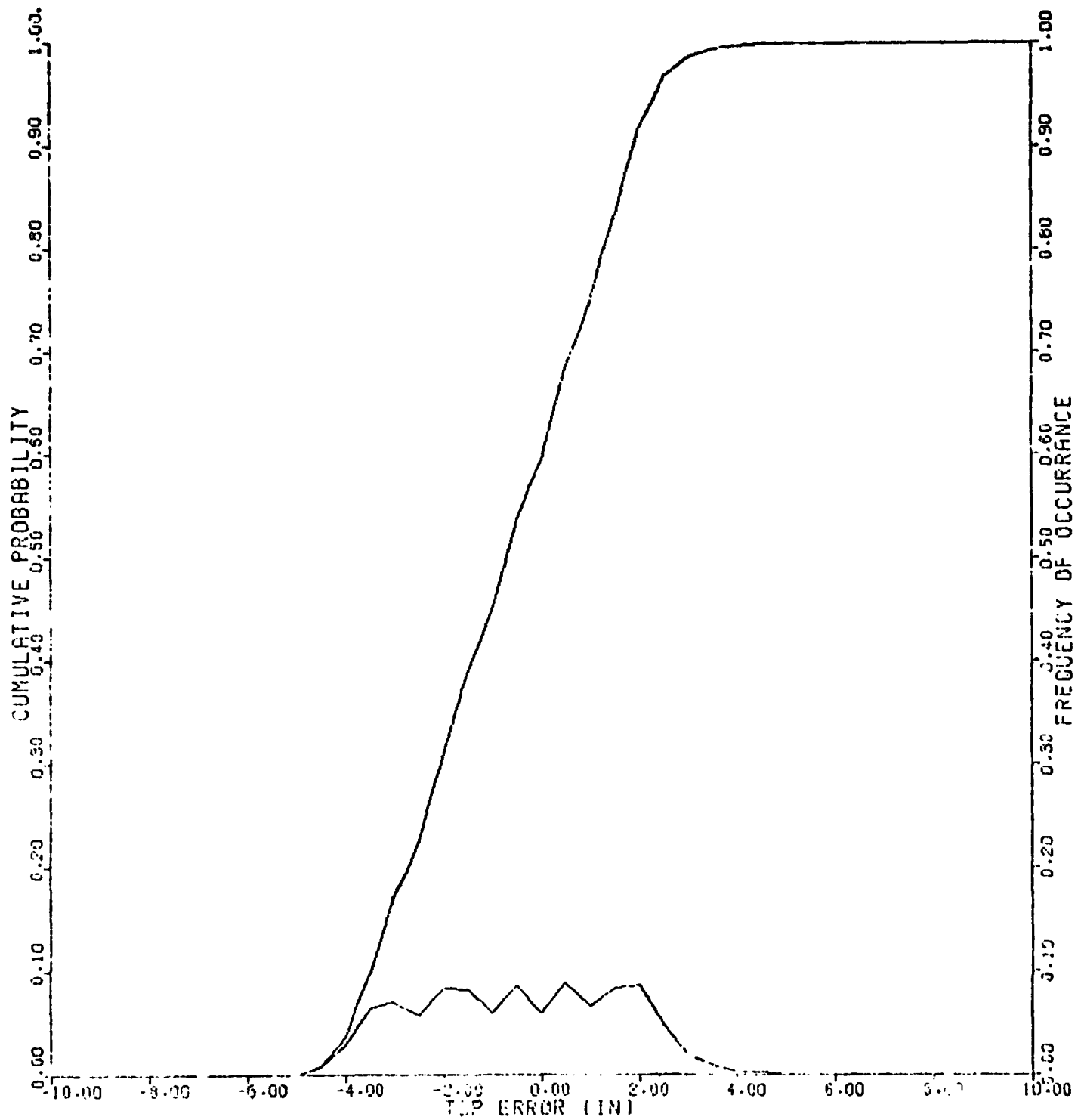


Figure 3-3. VCS Performance Using Passive Radiation CID with 5 in. Crystal (Page 5 of 5)

## PERFORMANCE EVALUATION

## PASS 1

TOTAL COAL TAKEN = 42.945 CU. FT.

AVERAGE CUT HEIGHT = 7.447 FT.

CUT STANDARD DEVIATION = 0.031 FT.

## FLOOR

RMS ERROR = 2.940 IN.

AVERAGE ABSOLUTE ERROR = 2.398 IN.

VOLUME EXCESS COAL LEFT = 63.103 CU. FT. ( 1.54%)

VOLUME EXCESS COAL TAKEN = 42.364 CU. FT. ( 1.03%)

VOLUME ROCK TAKEN = 4.685 CU. FT. ( 0.11%)

TIME IN ROCK = 8.84%

## ROOF

RMS ERROR = 1.941 IN.

AVERAGE ABSOLUTE ERROR = 1.617 IN.

VOLUME EXCESS COAL LEFT = 18.597 CU. FT. ( 0.45%)

VOLUME EXCESS COAL TAKEN = 55.511 CU. FT. ( 1.35%)

VOLUME ROCK TAKEN = 0.168 CU. FT. ( 0.00%)

TIME IN ROCK = 1.59%

Figure 3-4. VCS Performance Using Active Nucleonic CID (Page 1 of 5)

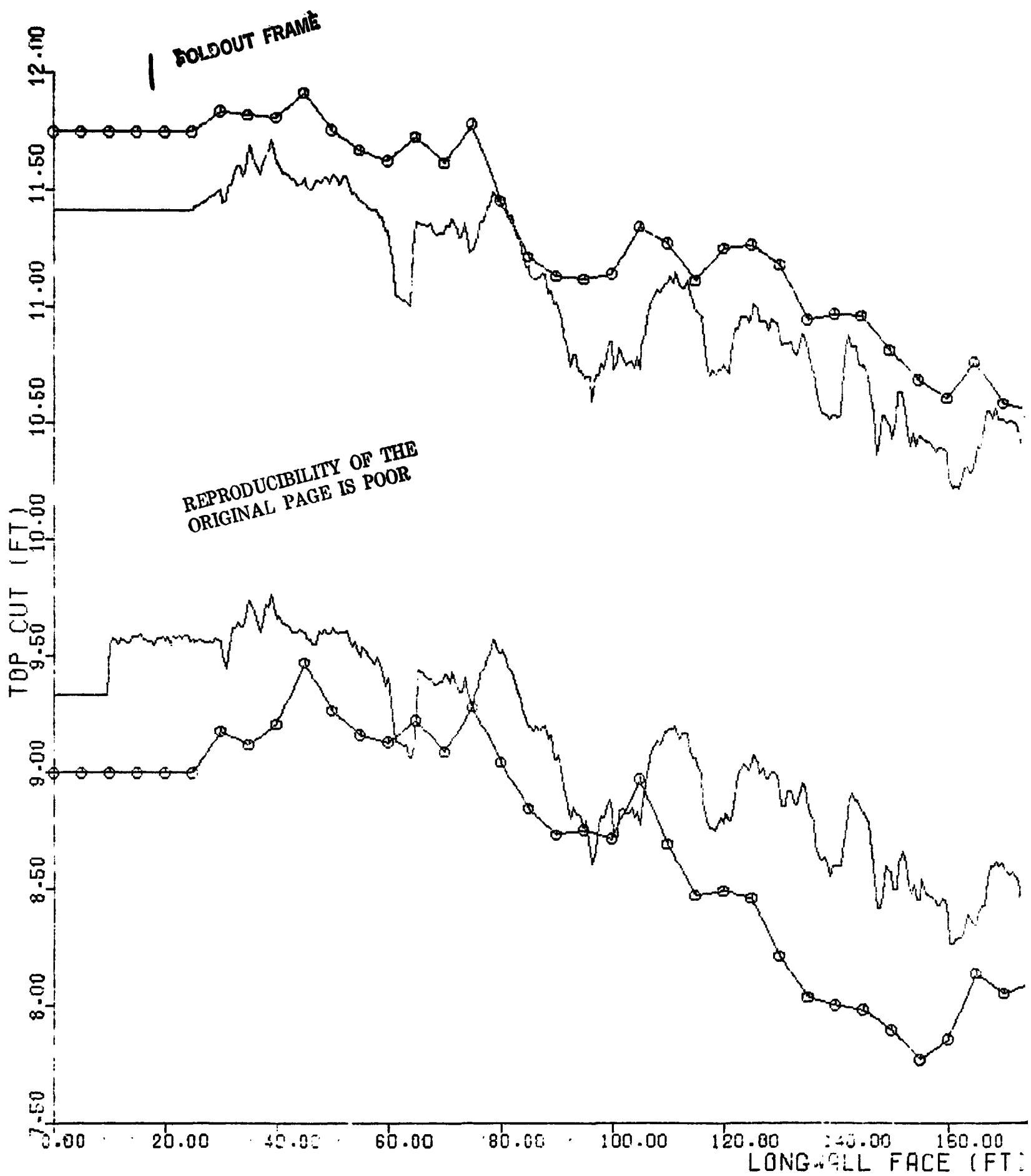
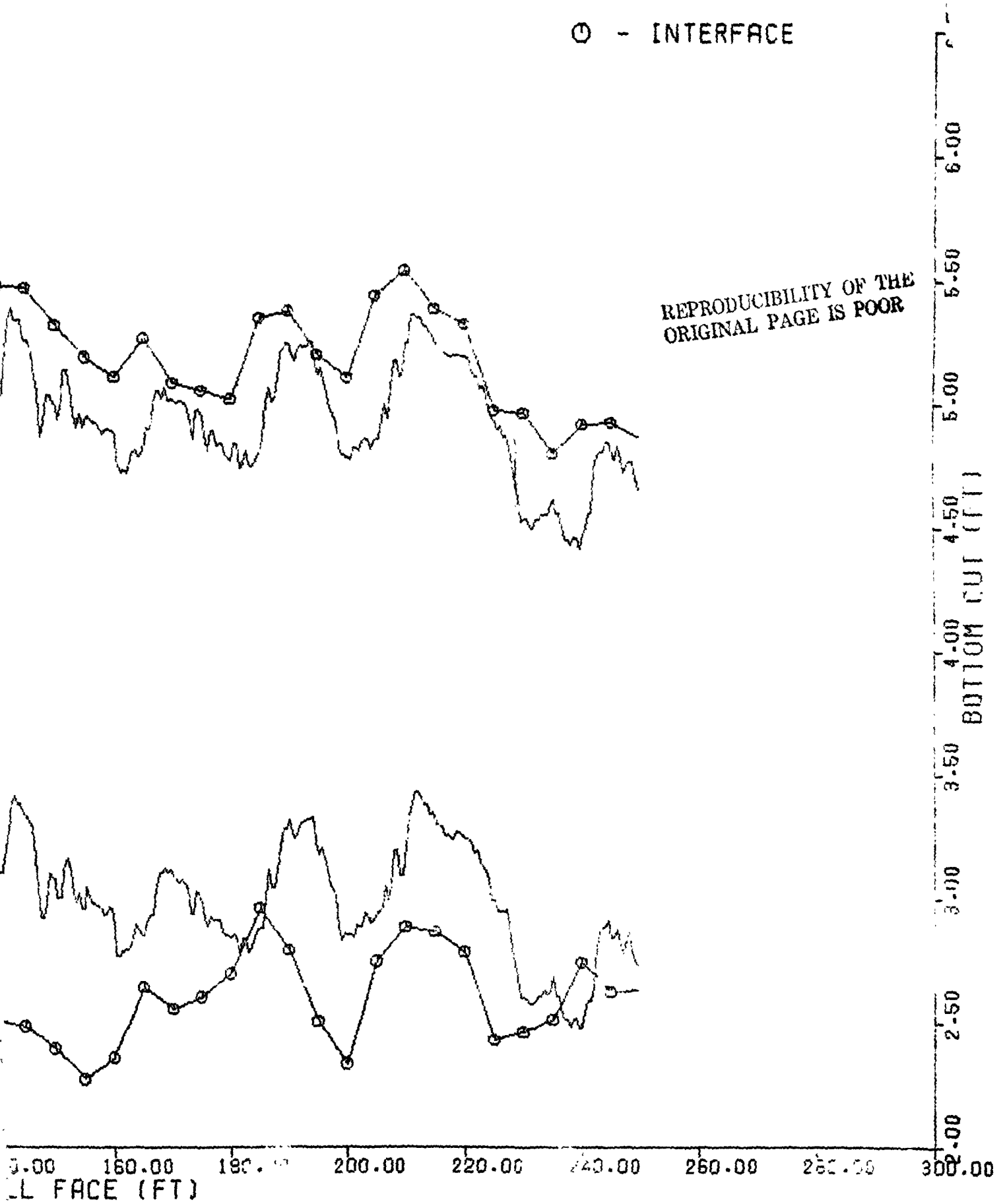


Figure 3-4. VCS Performance Using Active Nucleation

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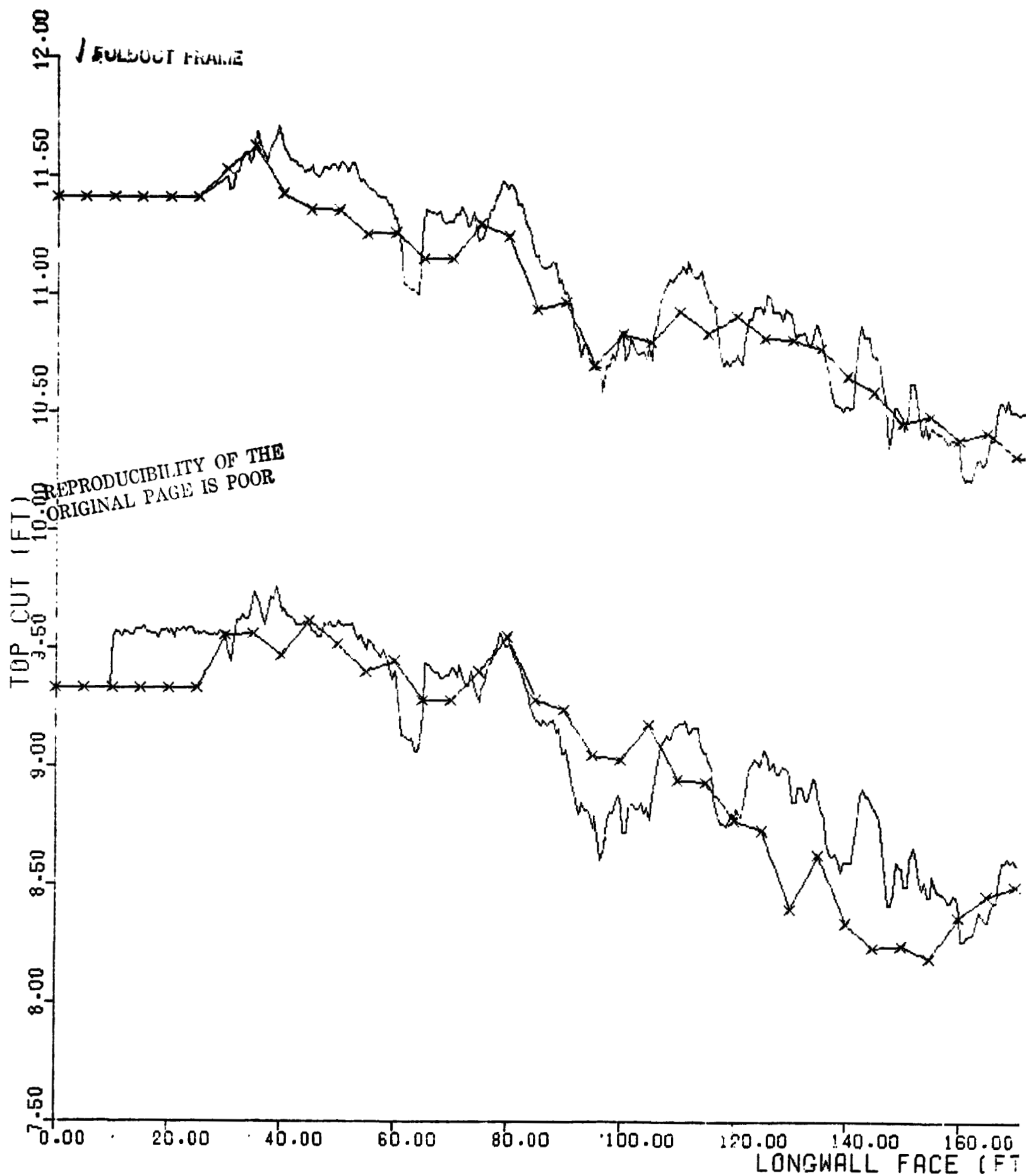
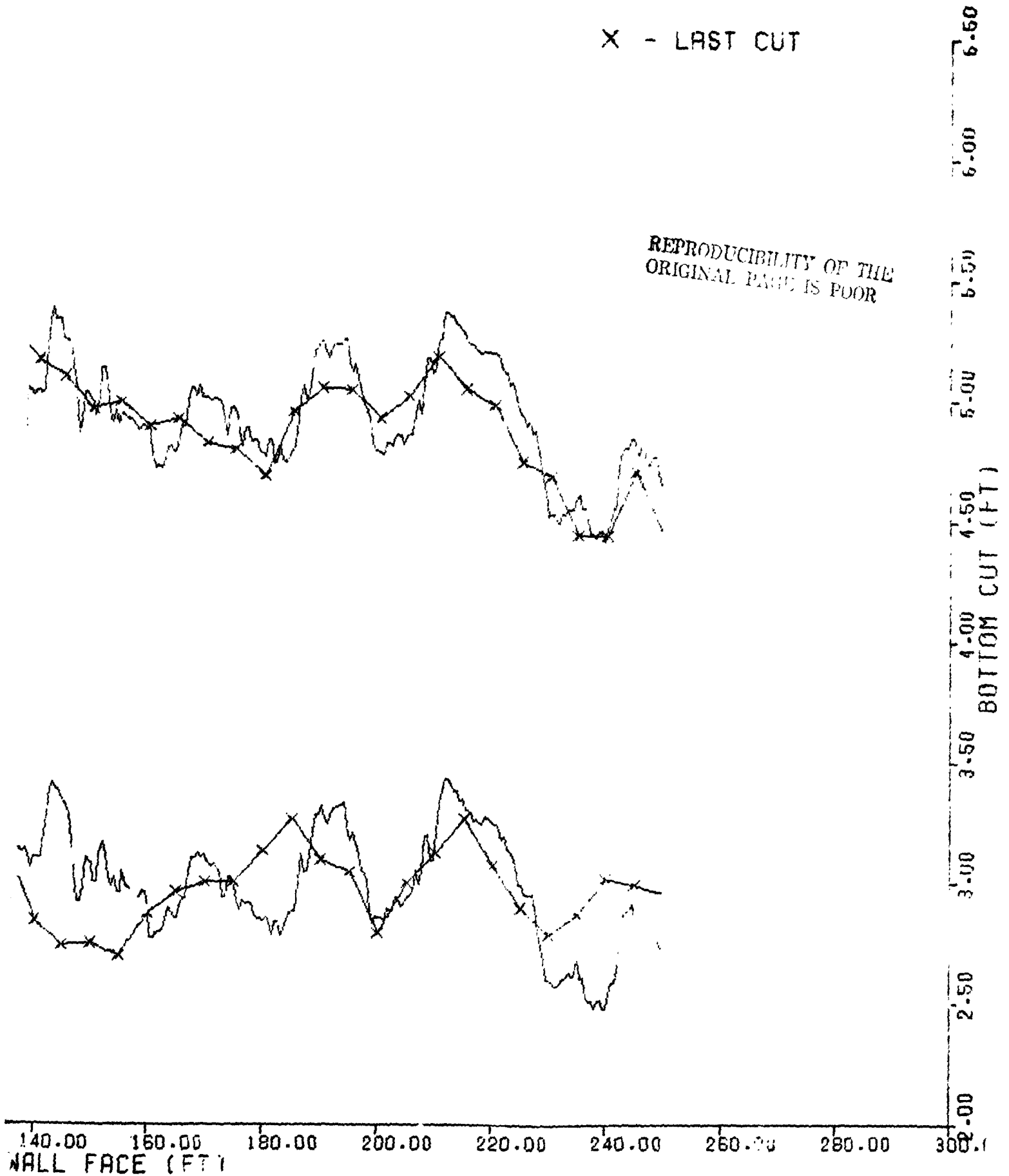


Figure 3-4. VCS Performance Using Active Nuc

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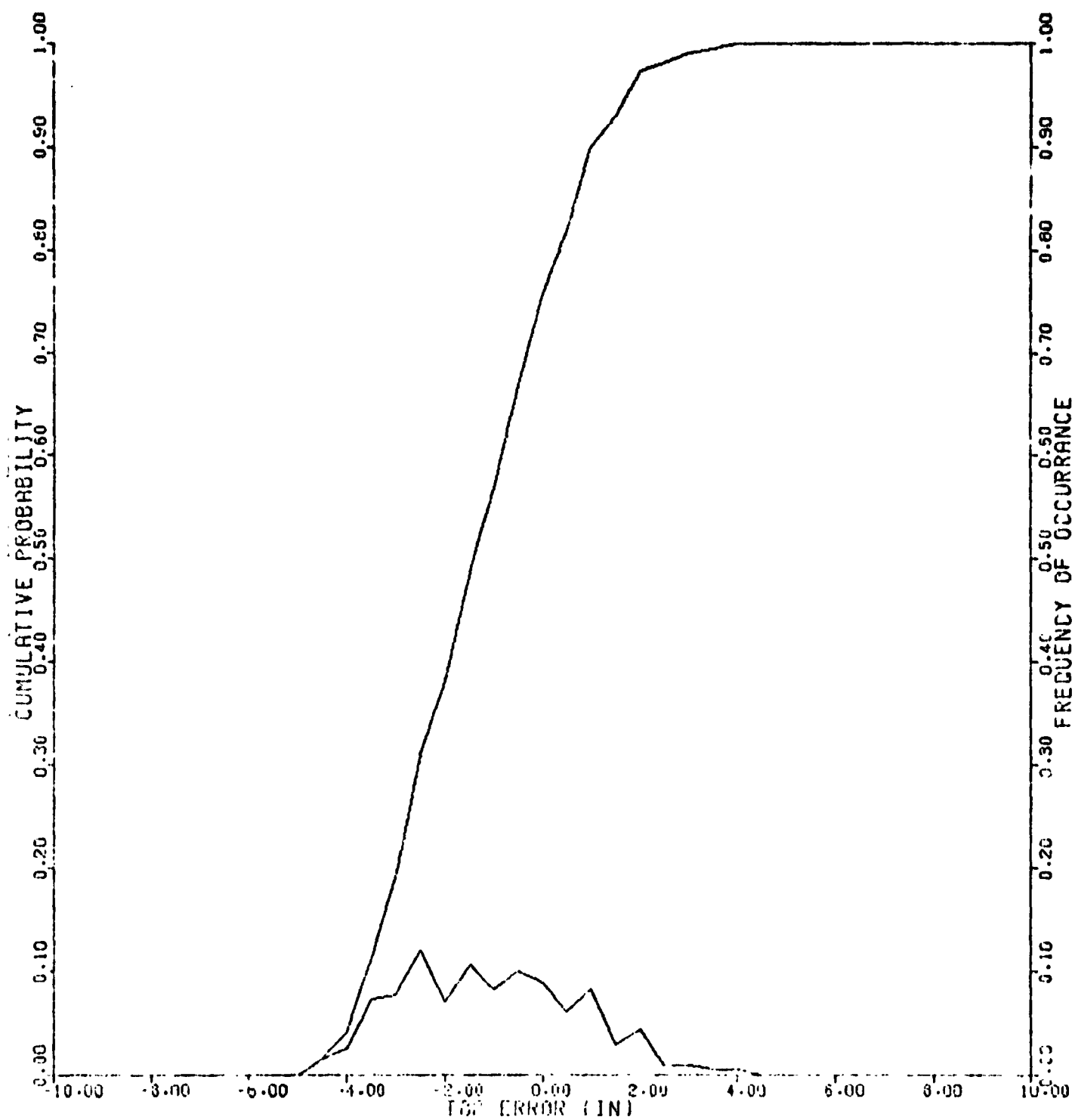


Figure 3-4. VCS Performance Using Active Nucleonic CID (Page 4 of 5)

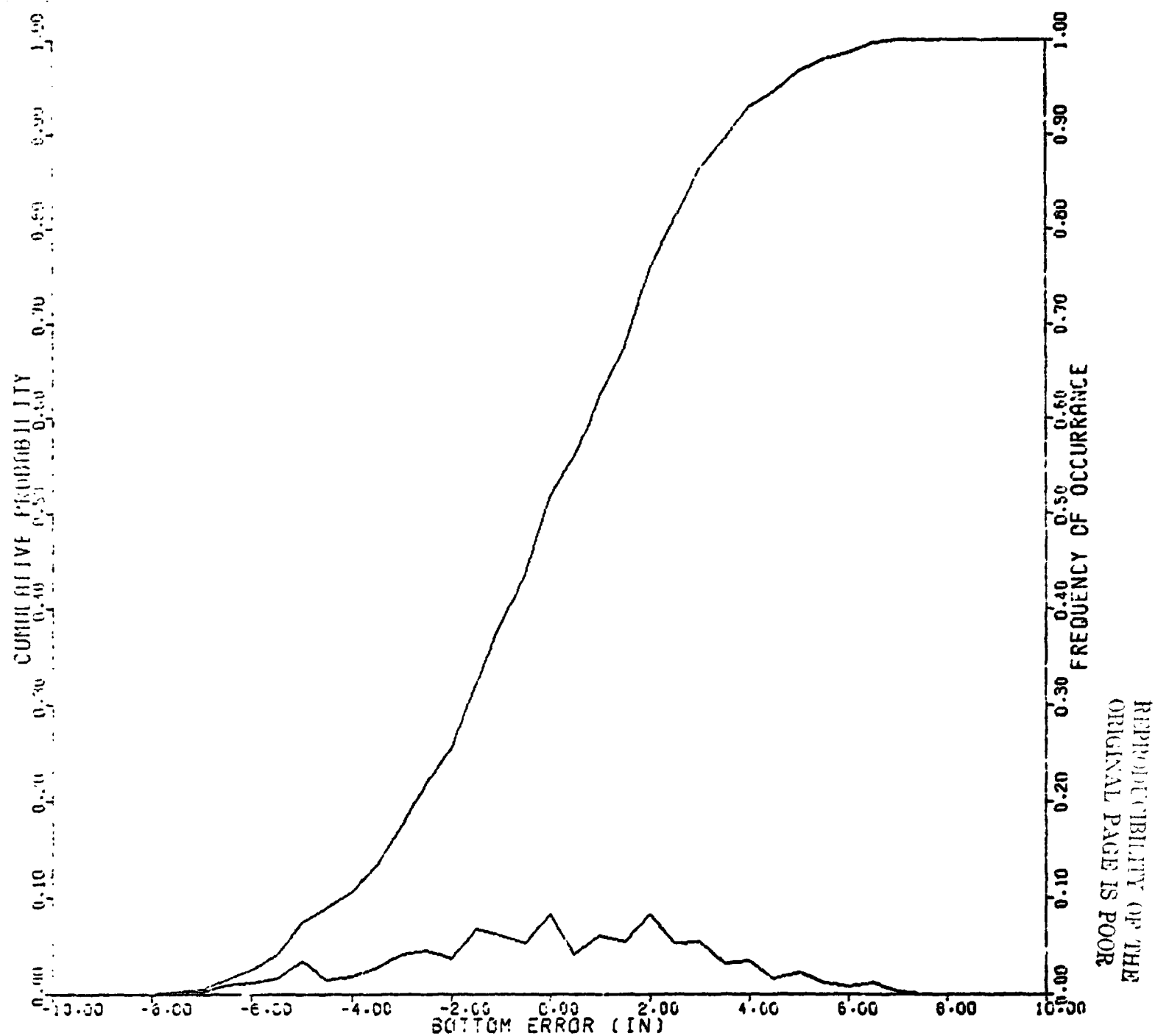


Figure 3-4. VCS Performance Using Active Nucleonic CID (Page 5 of 5)

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Table 3-4. VCS Performance with Active Nucleonic CID

PASS NO.	ROOF		FLOOR	
	RMS CUT ERROR (in)	PERCENT TIME IN ROCK (%)	RMS CUT ERROR (in)	PERCENT TIME IN ROCK (%)
1	1.94	1.6	2.90	8.6
2	2.04	5.0	3.17	5.8
3	2.10	4.9	2.98	3.1
4	2.29	9.4	3.0	5.2
5	2.52	11.2	2.95	2.4
6	2.69	17.2	3.32	6.7
7	2.33	7.2	3.21	4.0
8	2.20	6.8	3.27	8.3
9	2.12	5.9	3.25	11.0
10	2.03	4.08	3.14	9.8
AVERAGE OF LAST FIVE PASSES	2.32	8.73	3.19	7.03

ROBINSON RUN MINE  
WITH ACTUATORS  
SENSITIZED PICKS 90% ACCURATE  
4 IN BIAS  
PASSIVE RADIATION CID 4 FT BEHIND CUTTING DRUM  
0.5 SEC CID AVERAGING INTERVAL  
20 IN SEPARATION BETWEEN SOURCE AND DETECTOR

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#### **4.0 ELECTRONIC DESIGN OF THE LONGWALL VERTICAL CONTROL SYSTEM (VCS)**

The Automated Longwall Guidance and Control System consists of three major electronic hardware blocks, the Electronic Control Module (ECM) with its associated power supply, the Yaw Alignment System (YAS) Electronics, and the Master Control Station (MCS) with its associated power supply. The YAS electronics consists of electronic packages mounted on each of the roof supports to implement their proper advance command and control, and an angle cart device integrated with the shearer for measuring conveyor alignment from which roof support advance commands are generated. The MCS located in the headgate area (probably on the stage loader) is the central control and monitoring station for the Automated Longwall Guidance and Control System and virtually all system functions can be monitored and if desired controlled from this location.

The shearer mounted ECM is the electronic heart of the Automated Longwall Guidance and Control System containing most of the monitoring, command and control, and processing electronics including the central processing unit, required for automated longwall operation. As such the ECM contains the electronics for the three major control loops needed for automated longwall operation which are the Vertical Control System (VCS), the Roll Control System (RCS) and the Yaw Alignment System (YAS). The present portion of the study is concerned primarily with the design of the Vertical Control System portion of the Automated Longwall System and hence the primary emphasis will be on this design. However since a totally automated longwall system is desired, consideration was also given to the various other major electronic blocks and control loops where appropriate.

**4.1 Overall System Design of Automated Longwall System -** The function of the VCS is to control the two cutting drums of the double ended ranging arm Joy LW 300 Shearer so that they will remain within the coal seam. The VCS described herein is capable of taking all the coal on the roof and floor, or if desired, leave a given amount (i.e., bias) of head and/or floor coal while taking a minimum amount of rock. The VCS will maintain the distance between two successive cuts such that the roof supports may advance satisfactorily.

In addition to the VCS control of the drums as described in the preceding paragraph, the ECM is also configured to accept the sensor signals required to maintain the attitude of the longwall shearer about its longitudinal (roll) axis. This roll control is required to maintain a perpendicularity to the longwall panel being mined, and allow adjustment which will accommodate seam geometry.

Provisions have also been made in the ECM to accommodate the YAW alignment measurements and algorithms required to automatically advance the roof supports in such a manner that the conveyor "straightness" remains within acceptable limits and perpendicular to both headgate and tailgate.

**4.1.1 Top Level System Trade-Offs** - Before the preliminary design of the VCS and ECM could proceed some top level system trades had to be performed which are described below:

**4.1.1.1 Digital vs Analog Implementation** - As in any system design a trade that must be made is whether the system implementation should be analog or digital. One of the prime drivers in determining system implementation is the electromagnetic (E&M) environment that the equipment will be required to operate in. Due to the large electrical motors on the shearer proper (i.e., drum cutter motors, shearer haulage motor), and the large electrical motors that are required to drive the face conveyor, stage loader, and panel conveyor, the potential for E&M interference is high. It would be difficult to design an analog system that would operate reliably in the E&M environment present on the shearer and the longwall face area. Therefore, from an E&M viewpoint a digital system implementation, including digital sensor encoding wherever possible, would minimize the effects of E&M interference and is much preferred over its analog counterpart.

Given the complexity of the required longwall control, data processing, and status monitoring algorithms it would be very difficult to have an analog system implementation even if the algorithms would remain constant and not require change. However due to the variations in mining conditions and physical coal parameters the longwall algorithms will require periodic change and modification. By the use of digital techniques many control and operational parameters may be readily modified to meet changing environmental conditions by simply changing the program and reading the new program into the memory. This is considerably simpler than going into the mine environment during a maintenance schedule and modifying or replacing analog hardware. By designing the digital hardware properly the system configuration as well as its operating parameters become substantially software dependent and relatively hardware independent. A considerable level of sophistication has been achieved in the compiling of software and in devising useful special purpose software routines. The use of these techniques simplifies the design task to a considerable extent. In addition considerable engineering effort has been expended in the last fifteen years by industry to provide the systems engineer with a variety of thoughtfully designed digital building blocks further simplifying system design.

Due to the above outlined considerations a digital rather than analog design approach has been adopted for the automated longwall system.

**4.1.1.2 Software vs Hardware Trade Offs** - When the digital hardware is initially designed many of the tasks that must be performed may be performed either by simple programs operating in complex hard-

ware configurations or by complex programs operating in simple hardware configurations. In many cases the systems designer has degrees of freedom in assessing these trade offs. The basic philosophy used in the design of the VCS is to strive for simple hardware configurations.

**4.1.1.3 Multiplexing vs Direct Sensor Information Lines** - Once a digital system has been specified as the system implementation technique for the VCS, a trade is required to determine the manner by which sensor information is going to be transmitted to the ECM. The options that are available are to pass the essentially all digital sensor information directly to the ECM maximizing the number of lines going to and from the ECM but minimizing system electronic complexity; or to use multiplexing techniques which would minimize the number of lines going to and from the ECM at the expense of increasing VCS electronic complexity. In order to establish whether multiplexing of sensor information is desirable the number of lines between the sensors and the ECM were determined when sensor information is sent directly to the ECM. These determinations indicated that approximately 70 signal lines and ten power lines would be required to pass sensor information directly to the ECM from one of the shearer ranging arms. (This would be repeated for the other ranging arm. However, this is of no consequence in the evaluation since the multiplexing system would also have to be repeated for the other ranging arm) When considering digital multiplexing two general techniques are available i.e., serial and parallel digital multiplexing. Serial digital multiplexing would require the minimum number of lines since all data would be transmitted on a single pair of lines. This would result in a savings of approximately 68 signal lines since the power lines would still be required to power the various sensors. However, the electronic complexity introduced by serial digital multiplexing is considerable requiring Universal Asynchronous Receiver Transmitter (UARTS) in addition to the multiplexing and timing circuitry on the sensor end of the line. If parallel digital multiplexing is employed, the electronic complexity introduced although appreciable, would be less than serial multiplexing since UARTS would not be required. However the number of signal lines would increase from two to ten determined by the largest digital word required to be transmitted from the sensor (i.e., CID) location resulting in the saving of approximately 60 signal lines. It should also be noted that when employing multiplexing techniques the speed of the system is reduced, which is more severe for serial digital multiplexing, and a certain degree of flexibility is lost with respect to the manner in which data can be clocked into the CPU. It should be further noted that regardless of the multiplexing technique employed, cables from the ECM to the sensors would still be required for power, in addition to cables from the sensors to the junction box where the multiplexing system is housed. It hardly seems worth the electronic complexity introduced by multiplexing for the savings of the few relatively short cables from the junction box to the ECM that would result.

Therefore, as a result of these considerations, direct transmission of sensor data to the ECM has been chosen as the implementation technique for the VCS.

4.1.1.4 Minicomputer vs Microprocessor Trade Offs - After the analog/digital/software trade offs were evaluated and basic systems design decisions were established, the implementation with microprocessor vs minicomputer technology was studied.

The longwall system requires approximately 400 input/output (I/O) lines and also substantial computational power in the computer system selected. The minicomputer is superior to the microprocessor in computational power but has limited I/O capability. The microprocessor, on the other hand, is an ideal control device with powerful I/O structures but with limited computational ability. However an ample supply of building blocks, microprocessor compatible, which can enhance the computational ability for control applications are available. Typical of these building blocks are a number of arithmetic logic units (ALU's), microprocessor compatible, that have been developed for calculator applications. By interfacing one or more of these devices in a distributed processing network through the microprocessor I/O system a very nearly ideal systems solution was found. This solution provided a very powerful set of I/O command and control instructions together with a very powerful computational ability. This proved to be a contributing reason for the selection of microprocessor technology for this application.

A second, and important, advantage of the microprocessor is the ease of interfacing it to the sensors, encoders, hydraulic actuators, motor controllers and other auxiliary devices. A large number of microprocessor compatible chips are available to simplify this interfacing problem. Minicomputers, on the other hand, typically have a fairly complex I/O interface, primarily suited to data exchanges with EDP terminals, line printers, tape stations and disc files. Controllers may be designed to service large numbers of I/O lines, however it would be a more involved design than selecting another integrated circuit chip as would be the case with microprocessor technology.

A third and important reason for the selection of microprocessor technology is that of power limits which are intrinsically safe and thereby not requiring an explosion proof box. Typical of the TTL logic in a minicomputer is a J-K flip flop which can use up to 25 ma quiescent current. The same device in the CMOS microprocessor and logic families chosen, uses 250 micro-amp max, which is about 100 times less, enabling intrinsically safe power levels to be met.

A fourth and significant reason for the selection made is that of reliability. CMOS technology was primarily developed for reliability enhancement, a prime consideration when operating in the mine environment.

4.1.2 Operability - Operability, as a figure of merit, for the design of the longwall shearer consists basically of determining the answers to four questions:

1. At what rate does the system mine coal.
2. How long will it continuously mine coal before it experiences a repairable failure.
3. How long does it take to fix the repairable failure when it occurs.
4. How long do we operate with reduced or no coal production.

The design goal for coal mining rate is nominal operation at 30 ft/min with 50 foot per minute maximum traverse speed along the face with no appreciable degradation in performance. The mean time to failure and the mean time to repair are reliability and maintainability design goals to be established in the design phase of the program. It is clear that a mean time to failure figure in the hundreds of hours and a mean time to repair in the tens of hours are practical and readily obtainable with current technology.

4.1.2.1 Reliability - Reliability of the system is expressible in terms of mean time between failures (MTBF). The calculation of this number is performed by carefully summing weighted reliability indicies for each of the separate components of the system. These weighted indicies, when examined, are found to be a statistical composite involving component quality, power dissipation, operating temperature and voltage/current stress levels. Such a calculation cannot be performed until parts specification and detail design and analysis are complete.

The 30 foot/minute nominal traverse velocity for the shearer is established largely from considerations of improving the present coal mining efficiency by a factor of three to five. This means that the system must reflect MTBF numbers and mean time to repair (MTTR) numbers that do not detract from the operating performance targets.

During the design and development stage it is important to organize the design effort to assure industrial grade parts quality, low parts stress levels, power de-rating of components and a thermal design free of hot spots thus enhancing system reliability.

4.1.2.2 Maintainability - All physical systems are subject to some failure, sometime, under some set of conditions. When such a failure does occur with the longwall shearer it is important to be able to effect repairs quickly, easily and in the mine environment



where the failure takes place. This dictates that all functional components, i.e., box level, be replaceable easily and in the mine environment. This also dictates that the design be performed so that consequential failures are eliminated. If a single point failure occurs, the systems design must preclude the possibility of a fire cracker like string of consequential failures from being caused.

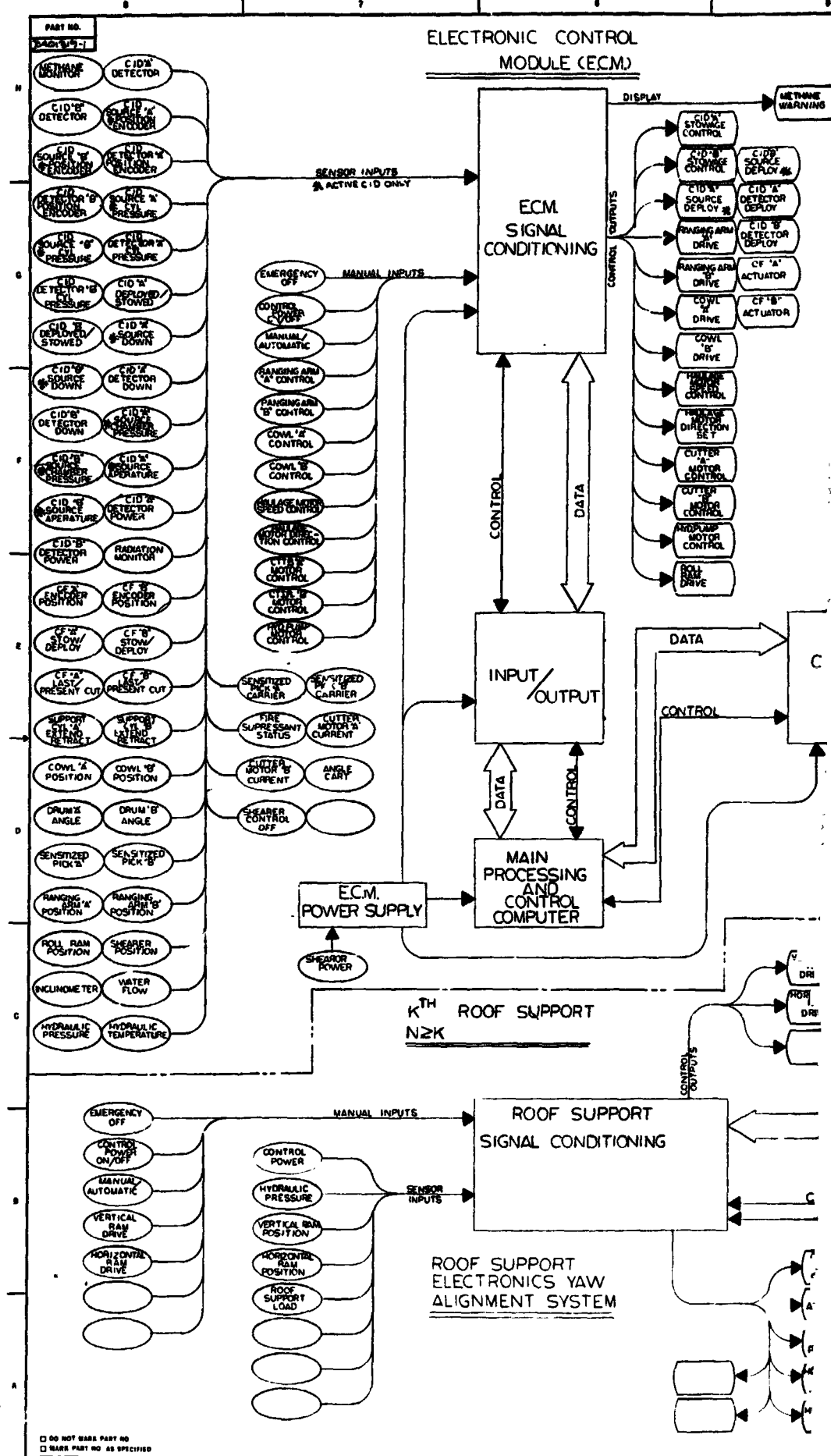
Major subsystems in permissible boxes must be easily diagnosed (by the DAS controller) and replaced quickly in the mine environment. The explosion proof boxes must be replaceable, in situ, in a reasonable amount of time. (i.e., within one maintenance shift)

Those subsystems that can be shown to have a very long MTBF, i.e.: cable harness, need not meet the simply and easily replaceable criterion.

**4.1.3 System Block Diagram** - Figure 4-1 is a block diagram showing how the longwall automation assemblies interface. The sensor and control inputs into the various assemblies are listed as are their control outputs. The data and control paths are also indicated for continuity in information flow throughout the longwall automation electronics. This diagram segregates the assemblies into the three major electronic hardware blocks consisting of the Electronic Control Module (ECM), the Master Control Station (MCS), and the electronics mounted on the roof supports which in conjunction with the shearer mounted angle cart form the YAW Alignment System (YAS). One roof support electronic subassembly is shown which is typical of the roof support mounted electronics employed along the longwall face. The communications subsystems are not separately defined and have been integrated within their respective subassemblies.

The Active Nucleonic CID was selected over the Passive Radiation CID in this preliminary design. This choice was made because its implementation was the more complex of the two and subsequent employment of the Passive Radiation CID could be accomplished by eliminating some hardware and a slight change in software. Had the Passive Radiation CID been chosen for this preliminary design, a subsequent change to the Active Nucleonic CID would result in a significant impact on the system hardware and software.

The ECM can be divided into four major subdivisions i.e., Signal Conditioning, Communications, Input/Output (I/O), and the Central processing unit (CPU). The functions and operation of each of these parts are described briefly in the paragraphs that follow.



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☐ MARK PART NO AS SPECIFIED

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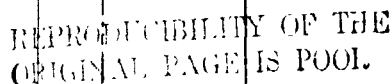


Figure 4-1.  
4-7

The ECM signal conditioning has been configured to supply power to and receive signals from all the sensors located on the shearer. These sensor signals vary from low level analog signals, through pulse streams of continuous data to absolute binary words. The sensor signals are conditioned and transformed into 8 bit binary words for use by the main processing and control computer via the input/output circuits. The manual inputs are conditioned in the same manner as the sensors into binary words or parts of words to represent the desired or selected control. These input signals are supplied to the input/output ports for use by the main processing and control computer.

The signal conditioning is also employed to receive signal commands from the main processing and control computer via the input/output electronics and properly drive the control devices listed. The signal conditioning transforms the digital words and bits into the appropriate control levels required for their respective control device, or to generate signals which in turn control high energy inputs required by some control devices.

Because of the intrinsically safe power levels desired in the Electronic Control Module (ECM), Industrial Grade Complementary Symmetry Metal Oxide Semiconductor (CMOS) technology and low power linear circuits are employed, where applicable. Also worthy of note at this point is that the CMOS technology was developed for high reliability and has a higher noise immunity for both power and input signals, than most other technologies.

The input/output portion of the ECM is employed to store data, conditioned by the signal conditioning, until the main processing and control computer has time to store and act upon that data. The input ports receive data from the signal conditioning and store it in 8 bit binary ports. At an appropriate time within the main processing and control computer algorithms, control signals are generated by the computer which place these 8 bit words, one at a time on to the 8 bit data bus for subsequent storage in the appropriate memory location within the random access memory of the microprocessor. These words are used by the computer in its algorithms or are transferred to the control and display console via the communications portion of the ECM.

The input/output employs industrial grade CMOS technology exclusively because of its low power consumption, which enables the maintenance of intrinsically safe power levels with this degree of complexity. The other reasons of reliability and noise immunity previously discussed are also applicable when justifying a choice of CMOS technology.

The communications portion of the ECM system is a micro-processor based subsystem employed to transfer voice and data from the shearer to the control and display console and the roof support electronic subassemblies. This voice and data link also provides for the voice and data from the control and display console to the shearer and from the roof supports to the shearer.

The communications subassembly provides the mechanism for loading initial constants into the random access memory of the main processing and control computer. These constants are generated and stored in the processor located in the control and display console. The communications subsystem also provides the mechanism for interrogation of the shearer from the Master Control Station (MCS).

As before, industrial grade CMOS technology has been employed, where practical, because of low power consumption, high reliability, and high noise immunity on both power and signal lines.

The main processing and control computer is a microprocessor based subassembly employed to provide the intelligence for operation of the longwall system in the automatic and remote modes of operation and to provide fault and status monitoring of the longwall system. This subassembly contains the control algorithms required for control of the shearer and roof supports and for monitoring of the status and faults within the shearer electronics.

The CPU strobes sensor or control data from the input/output ports for use, and also stores data for use by the control and display console. Commands are loaded into ports of the input/output electronics for conditioning and subsequent use by control devices of the shearer. Additional data transfers to and from the control and display console and roof support subassemblies. This is accomplished by the CPU opening up its data and address bus lines at a specific time whereby the communication subassembly may obtain data from and modify its random access memory with appropriate data.

As before, industrial grade CMOS technology is employed where practical because of its low power, high reliability, and high noise immunity.

The ECM has controls on the front panel which are only used in check out of the ECM. The manual controls, employed for manual operations, are a part of the original Joy equipment and will continue to be the controls when the shearer is manually operated.

Direct wires, cables, and junction boxes have been selected for transferring the signals from the sensors on the shearer to the ECM. This choice was made over serial digital, and parallel digital multiplexing after an evaluation was made between these techniques.

Figure 4-2 indicates the location of the ECM and its power supply, the approximate location of the sensors and control devices, and their respective cables and approximate routing. Note should be made at this point that a portion of the cables shown will be routed inside the machine plating and all exposed cables will be covered with protective conduit or shielding as required to adequately protect them.

The ECM box is bolted to the top of the shearer in the approximate location shown in Figure 4-2 through shock absorbing feet configured to absorb a portion of the vibrations encountered during the cutting operation. Should a drilling and bolting operation not be practical, for whatever reason, a bracket will be bolted to the ECM box and in turn welded to the top plate of the shearer. The ECM box is protected from heavy falling objects encountered during mining operations by a shield welded or bolted to the top plate of the shearer.

The power supply box, being an explosion proof box, is bolted directly to the top plate of the shearer and requires no protective shield. The ECM and power supply boxes are both water and dust proof to prevent contamination of the electronics by the water spray and dust present on the longwall face. All of the high energy control elements which cannot be made intrinsically safe are mounted in the explosion proof Power Supply Box. The outputs of the power supply box is either redundantly current limited to intrinsically safe levels or employ mine permissible explosion proof cables operating through packed glands. The ECM box is configured to be intrinsically safe by maintaining power levels and energy storage devices (i.e., capacitors and inductors) within acceptable limits thus making all of the shearer mounted electronics permissible or intrinsically safe.

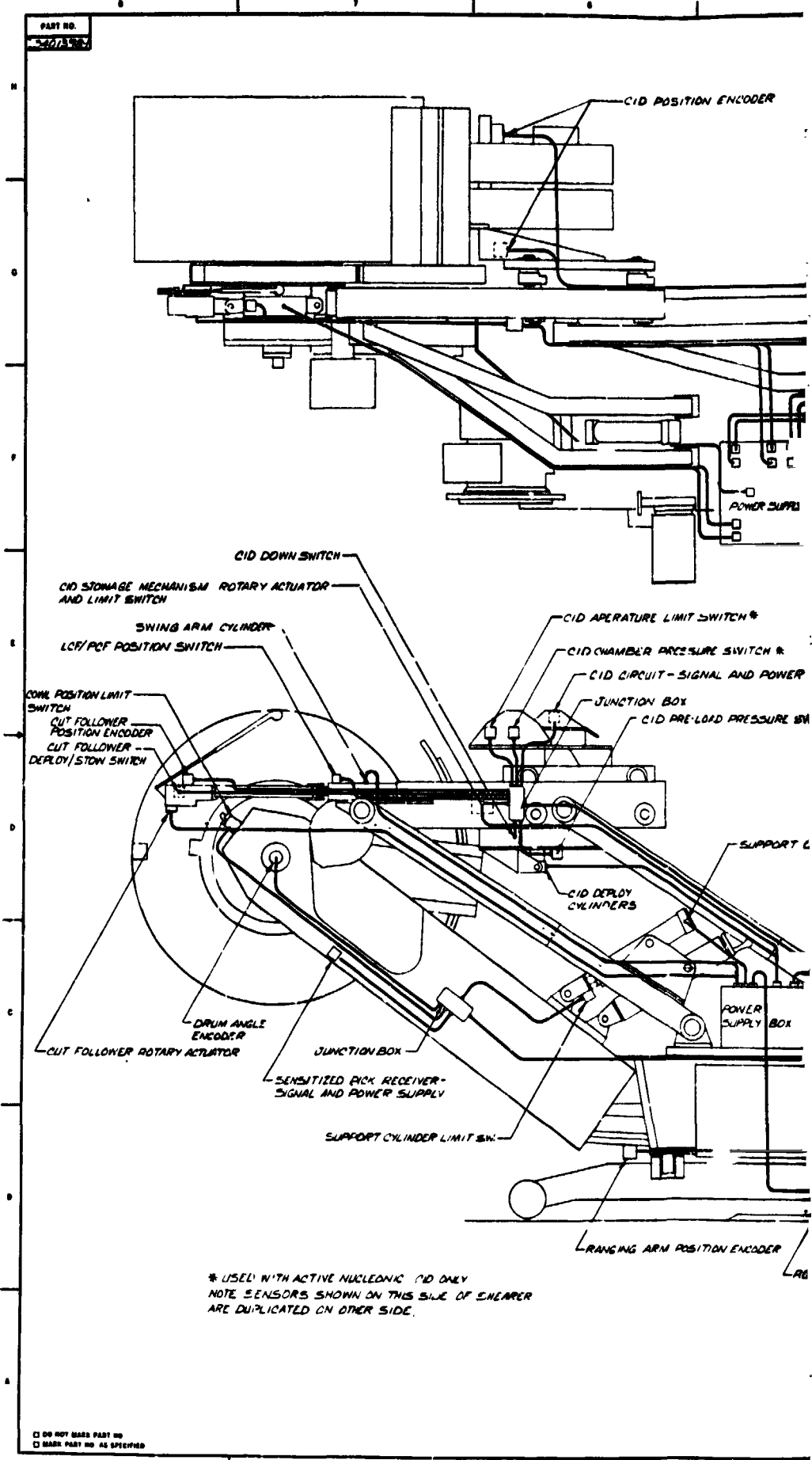
**4.1.4 Safety** - Precautions have been taken in the preliminary design in both control implementation and sensor application to make the automated longwall equipment and its operations safe.

**4.1.4.1 Methane** - The methane monitors currently employed on the Joy shearer as well as its present control and shutdown procedures are still used for methane protection. The ECM accepts signals from the methane detector for display on the shearer and to transmit to the Master Control Station a signal for display and warning at that location. In addition to the display and warning the ECM will perform a redundant shutdown based upon methane levels  $\geq 2\%$ .

**4.1.4.2 Radiation** - When the Active Nucleonic CID is employed precautions have been taken to detect malfunctions within the radiation source which may cause radiation leakage. The following malfunctions are detected by sensors located on the shearer and cause an audible alarm to be sounded on the ECM front panel with or without system power.

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1 FOLDOUT FRAME







1. Source chamber pressure switch is employed to sense the loss of pressure within a pressurized chamber which indicates the possibility of a rupture in this chamber which could emit radiation.

2. Source aperture open switch in conjunction with the cylinder pressure switch (preload pressure) to indicate the source is not at the roof and not covered. This indicates the possibility of radiation being emitted into the mining area rather than up into the roof only.

3. Shearer mounted radiation detector which senses excessive radiation in the proximity of the detector.

4.1.4.3 Fire - Fire sensors have been employed on board the shearer to detect excessive heat. Detection of excessive heat will cause the release of a fire retardant and initiate shearer shutdown. If the shearer is already shutdown the fire retardant will also be released.

4.1.4.4 Roof Support Precautions - In order to provide safe penetration of the longwall mining face and roof support area by mining personnel, provisions have been incorporated within the design for access keys to be located on roof supports on each end of the longwall face. When penetration is desired a key is removed from its roof support which will disallow power to the shearer and roof support systems. Power can only be activated after all keys are returned to the roof support access key positions. Personnel concerned with their safety would not enter into the face area without possession of a key. This is essentially the same safety procedure used by the power industry to avoid circuit breaker turn on while maintenance personnel are located along the power line.

4.1.4.5 Control Precautions - Precautions have been taken within the control algorithms to prevent hazards where possible. These hazards control algorithms follow.

1. Prior to automatic operation, all control switches on board the shearer must be in the off or neutral position. Any change from the off or neutral position will revert the shearer and MCS to manual mode and thereby require the initialization/start up procedure to be performed.

2. Whenever the system is either shutdown, or the automatic/remote is being selected after the shearer has been in manual mode, the system will be required to go through its initialization sequence before the automatic/remote mode of operation is enabled.

3. Manual entry into the system operation from the Control and Display panel keyboard (DAS) requires the use of a controlled access key. The access to the key is limited to knowledgeable and responsible parties.

4.1.4.6 Mine Permissibility - In order to make the ECM permissible those circuits and signals which cannot be made intrinsically safe are housed in an explosion proof box. Power and signals entering or exiting from the explosion proof box shall pass through explosion proof glands and MSHA approved cable.

The circuits and signals that are intrinsically safe are housed in the ECM power supply box. Control power (110 V AC at 60 cycle) comes from the Shearer Main Control Case, through explosion proof cable and into the ECM power supply box through an explosion proof gland. Power is regulated within the power supply box and is redundantly current limited to intrinsically safe levels prior to its routing to the ECM electronics box. These intrinsically safe power levels are specified by a series of curves depending on resistance, inductance, and capacitance load values which are documented in the SMRE Research Report titled "Some Aspects of the Design of Intrinsically Safe Circuits" published by the Ministry of Power Safety in Mines Research Establishment", Red Hill, off Broad Lane, Sheffield 3, England.

Estimates of the ECM electronics power requirements were based on past experience with systems of similar complexity. The estimated power requirements are as follows:

1. + 5 VDC at 10 amps
2. + 12 VDC at 0.40 amps
3. - 12 VDC at 0.40 amps
4. + 28 VDC at 0.2 amps

These power lines are made intrinsically safe by redundantly limiting the current levels and routing them from the power supply box through an explosion proof gland and MSHA approved cable. The power limits are as follows:

1. + 5 VDC - three power lines are required each of which are redundantly current limited to 3.5 amps. Each line is further constrained such that its inductive load shall not exceed 1 microhenry and its capacitive load shall not exceed 1000 microfarad. These levels are significantly below the 6 amp level at 5 volts specified for intrinsic safety by the SMRE Research Report quoted above.

2. + 12 VDC - four power lines are required, each of which is redundantly current limited to 0.10 amps. Each line is further constrained such that its inductive load shall not exceed 5 milihenry and its capacitive load shall not exceed 0.5 microfarad. These levels are significantly below the 0.15 amp level at 24 volts (+ 12) specified for intrinsic safety by the SMRE Research Report quoted above.
3. - 12 VDC - four power lines are required, each of which is redundantly current limited to 0.10 amps. Each line is further constrained such that its inductive load shall not exceed 5 milihenry and its capacitive load shall not exceed 0.5 microfarad. These levels are significantly below the 0.15 amp level at 24 volts (+ 12) specified for intrinsic safety by the SMRE Research Report quoted above.
4. + 28 VDC - three power lines are required, each of which is redundantly current limited to 0.07 amps. Each line is further constrained such that its inductive load shall not exceed 5 milihenry and its capacitive load shall not exceed 0.5 microfarad. These levels are significantly below the 0.13 amp level at 28 volts specified for intrinsic safety by the SMRE Research Report quoted above.

The 110 VAC lines to drive the control actuators are controlled from circuits within the explosion proof power supply box and routed to actuators through explosion proof glands and MSHA approved cables.

4.2 Design of CPU - The preliminary design of the main processing and control computer was accomplished in several stages. The first stage was that of generating the algorithms and sequencing required for the automation of the vertical control system of the Joy Longwall shearer previously noted. These algorithms and sequencing requirements were then transformed in to the operational flow diagrams which follow. The flow diagrams and their attendant descriptions were then employed to size hardware required as well as the technology chosen for the CPU.

The following flow charts, block diagrams and descriptions are the resultant of the operational requirements conceived to be the needs for automation of the longwall shearer.

**4.2.1 Operational Requirements** - The vertical control system (VCS) operates as a microprocessor controlled closed loop control system. Sensory data about real time operation of the shear is made available to the microprocessor. The microprocessor then provides output commands to the longwall shearer based on its input sensory data and on the control law algorithms required for satisfactory machine operation.

The VCS provides for automatic, remote and manual operation of the longwall shearer cutting arms. In the automatic mode of operation the system is under control of the microprocessor and its pre-programed control algorithms. In the remote mode of operation the system is under the control of the control and display panel, i.e., Master Control Station, and may be directed in all of its operations under pushbutton control. In the manual mode of operation the system is under the control of the manual control panel located on the shearer.

The manual mode of operation is a preemptory mode of operation; i.e. it will take over system control from the automatic or remote modes at any time the manual switch is operated. The system will also go into the manual mode of operation any time a key is removed from a lockswitch on the roof support. This is an auxiliary function not under Main Processing and Control Computer (MPCC) control.

In all three modes of operation the MPCC operates to provide status information to the C&D panel. In all three modes of operation the MPCC will monitor hazard sensors and place the shearer in an emergency power off or in a shearer power off condition, if necessary from safety considerations.

The software is designed as a block structured series of relatively independent subroutines interconnected by conditional calls in a master program (LINKUP). These subroutines are listed in Table 4-1.

LINKUP, Figure 4-3, provides for five defined states of operation:

1. Power on initialization
2. Normal operation; automatic, remote or manual
3. Normal power off operation
4. Emergency shut down of system
5. Shut down of shearer

Table 4-1. List of Firmware Routines

<u>FUNCTION</u>	<u>FIGURE</u>	<u>ROUTINE</u>
MASTER MONITOR PROGRAM	4-3	LINKUP
LOADS PARAMETRIC DATA AT TURN ON	4-4	LOADER
ROLL RAM CONTROL ALGORITHM	4-5	ROLRAM
VCS TURN ON PROCEDURE	4-6	VCSGO
EMERGENCY SHUTDOWN	4-7	HELP
MALFUNCTION SHEARER POWER OFF	4-8	SHRDON
REMOTE AUTOMATIC MODE SEQUENCE ON	4-9	RAMS
STATUS MONITOR	4-10	STATDO
CID CALIBRATION CORRECTION	4-11	CALCULE
LEAD DRUM CONTROL ALGORITHM	4-12	LEDNUM
TRAILING DRUM CONTROL ALGORITHM	4-13	TRADRUM
NORMAL POWER OFF SEQUENCE	4-14	PWRDON
SHEARER TURN AROUND ALGORITHM	4-15	SHROND
MANUAL MODE CONTROL SEQUENCE	4-16	MALSEQ
ROLL RAM POSITION SERVO LOOP	4-17	

LINKUP may be accessed through operator intervention at either the C&D panel or the manual control panel. During the power on initialization phase of LINKUP the system switches are checked to be in the correct position, the parametric data is loaded into memory and the microprocessor is initialized to its starting location. LINKUP also provides for emergency power off (HELP), power off of shear (SHRDON) and normal power off operation (PWRDON). As the LINKUP program executes it continuously tests to determine hazardous or malfunctioning conditions that would trigger the HELP or SHRDON power down command. As the linkup program executes it tests the auto-remote-manual switches and puts the system in the appropriate mode of operation.

4.2.1.1 **LOADER** Figure 4-4 - This subroutine provides for the loading of the RAM memory on the shearer. The basic operation of the program calls for the MPCC, under ROM control, to continuously, on each program pass, look for a switch setting that will cause it to go to a LOADER subroutine resident in the communications ROM. This resident loader will then load the parametric data from the C&D panel via the communications link into the common access memory. At the conclusion of the load operation the switch will clear and the MPCC will start executing ROM based instructions with the new RAM based data in memory.

The parametric data thus loaded is as shown in Table 4-2.

The control microprocessor at the conclusion of the LOADER subroutine will then go to the VCS GO subroutine.

4.2.1.2 **VCSGO** Figure 4-6 - VCSGO is the turn on procedure for the vertical control system (VCS). The VCSGO subroutine examines VCS status and will cause the system to do one of four things.

1. Enter the emergency shutdown (HELP)
2. Enter the shearer power down (SHRDON)
3. Illuminate the green status ready flag
4. Halt and await operator intervention

Those hazardous conditions that will cause the system to initiate emergency shutdown (HELP) are as follows:

Methane  $\geq$  2%

CID pressure out of limits

Table 4-2. Parametric Data Base

FUNCTION

1. DIRECTION OF TRAVEL
2. MINING CONDITION
3. LAST CUT FOLLOWER VALUE
4. SEAM HEIGHT
5. CUT HEIGHT
6. BOTTOM DRUM CONTROL HEIGHT
7. LENGTH OF CUT
8. DIFFERENCE BETWEEN TWO SUCCESSIVE CUTS
9. CID POLYNOMIAL COEFFICIENTS
10. LEDRUM RANGING ARM HEIGHT LOOKUP TABLE
11. LEDRUM ACTUATOR DRIVE LOOKUP TABLE
12. HAULAGE RATE
13. TRADRUM BOTTOM DRUM HEIGHT LOOKUP TABLE
14. TRADRUM ACTUATOR DRIVE LOOKUP TABLE
15. ROOL RAM ACTUATOR DRIVE LOOKUP TABLE
16. SEAM INCLINATION
17. REFERENCE TABLE

CID radiation out of limits

CID aperture cover not properly closed

The last three listed hazardous conditions apply only to systems using the Active Nucleonic CID. The Passive Radiation CID has no corresponding hazard monitor conditions.

Those malfunction conditions that will cause the system to initiate shearer power down (SHRDON) are as follows:

1. Fire suppression equipment not ready at end of cut.
2. CID voltage/current unsafe limit
3. Last cut follower not positioned.
4. Present cut follower not positioned.
5. Sensitized pick carrier not sensed.

Each of the shearer power down and each of the emergency power down conditions will cause an error data bit to be sent to the C&D panel to where it may be used to set a warning indicator. All of the shearer power down conditions provide for operator capability to over-ride the particular malfunction indicator. No over-ride capability is provided for a hazardous condition (HELP) shutdown. In the case when the voltage/current exceeds a preset limit the CID only is shutdown. There will be a warning indicator sent to the C&D panel but no over-ride capability is provided for this error. Prior to VCS GO, the program senses all switch positions in the system and compares their position to a preset table. In the event a switch is not in its proper position for start up the system will send a warning indicator to the C&D panel then halt and wait for the switch to be correctly set. Two other indicators are sent to the C&D panel during VCS GO to further define the methane status. If methane is less than 2% but greater than 1% a warning indicator (yellow) will be sent to the C&D. If methane is below 1% than a status ready flag will be sent to the C&D panel to illuminate a green indicator. The system will continue to operate during a methane yellow status condition.

If none of the hazards or malfunctions is detected during VCS GO it will send a status ready indicator to the C&D panel to illuminate a green ready indicator. The system will then revert to the LINKUP monitor which will determine the next step.



4.2.1.3 RAMS Figure 4-9 - If the VCS GO status check program successfully goes to completion, the LINKUP program then checks the mode buttons. If the system has been put in automatic then the remote automatic mode start up (RAMS) routine is initiated. This routine will auto sequence the shearer to the on operational condition. This routine has three normal exits; they are:

1. Abnormal completion of startup (EXIT HALT)
2. Malfunction termination (SHRDON)
3. Normal completion of startup (EXIT)

The EXIT HALT condition caused by one of the abnormal start up conditions of Table 4-3 automatically causes the program to send the appropriate indicator to the C&D panel to alert the operator and then to revert to the status monitoring mode while awaiting the operators intervention via the over-ride option. In the event that the operator does not intervene with the over-ride, the system will remain in the status monitoring (STAT GO) condition and will not complete the start up sequence. In the event the abnormal start up condition is cleared or over-ridden the RAMS routine will proceed. In each case of malfunction the malfunctioned step, when detected, will be shut down and the start up over-ride must be present to allow it to proceed.

In the event that the RAMS routine encounters a malfunction termination condition during its sequencing it will send the appropriate indicator to the C&D panel, wait a defined time, during which it looks for over-ride and does status monitoring. If over-ride does not occur during the allotted time the RAMS routine will power down the shearer (SHRDON) then the system will revert to status monitoring (STAT GO). The malfunction termination conditions are listed in Table 4-4.

In the event that RAMS sequences through its assigned tasks without abnormal completions (EXIT HALT) or malfunction terminations (SHRDON) it will send a data bit to the C&D panel to illuminate a green status ready indicator and revert to the LINKUP monitor to decide upon the next program sequence.

4.2.1.4 LINK UP MONITOR in Automatic Mode - When the automatic mode is selected and at the completion of RAMS the system will enter an operating loop that contains seven discrete sequences; these sequences are:

1. STATDO    Status Monitor
2. CALCULE   Calculate Coal Overburden Thickness
3. LEDRUM    Control the Lead Drum

**Table 4-3. Abnormal Start Up Conditions**

- 1) **PARAMETER DATA NOT ENTERED**
- 2) **SENSOR DATA NOT ENTERED**
- 3) **PANEL CONVEYOR MOTOR CURRENT LIMIT**
- 4) **STAGE LOADER (RIGHT) MOTOR CURRENT LIMIT**
- 5) **STAGE LOADER (LEFT) MOTOR CURRENT LIMIT**
- 6) **FACE CONVEYOR (HEADGATE) MOTOR CURRENT LIMIT**
- 7) **FACE CONVEYOR (TAILGATE) MOTOR CURRENT LIMIT**
- 8) **HYDRAULIC PUMP PRESSURE LIMIT**
- 9) **HYDRAULIC FLUID TEMPERATURE LIMIT**
- 10) **CUTTER (LEADING) MOTOR CURRENT LIMIT**
- 11) **CUTTER (TRAILING) MOTOR CURRENT LIMIT**

**Table 4-4. Malfunction Terminations Conditions of RAMS**

- 1) WATER FLOW LIMIT
- 2) RIGHT COWL NOT SET CORRECTLY
- 3) LEFT COWL NOT SET CORRECTLY
- 4) UNUSED LCF NOT STOWED CORRECTLY
- 5) UNUSED CID NOT STOWED CORRECTLY
- 6) UNUSED PCF NOT STOWED CORRECTLY
- 7) USED LCF NOT DEPLOYED CORRECTLY
- 8) USED CID NOT DEPLOYED CORRECTLY
- 9) USED PCF NOT DEPLOYED CORRECTLY
- 10) HYDRAULIC PRESSURE LIMIT
- 11) LCF NOT CONTACTING ROOF CORRECTLY
- 12) WRONG OR MISSING CUT VALVE IN PARAMETER TABLE
- 13) WRONG OR MISSING SEAM HEIGHT IN PARAMETER TABLE
- 14) WRONG OR MISSING CUT HEIGHT IN PARAMETER TABLE
- 15) WRONG OR MISSING BOTTOM DRUM CONTROL HEIGHT IN PARAMETER TABLE

4. TRADRUM Control the Trailing Drum
5. ROLRAM Control Shearer Inclination
6. SHROND Assist the Manual Turn Around
7. ROOF UP Control the Roof Supports
8. Revert back to STATDO

This sequence will continue until interrupted by emergency power down (HELP), shearer power down (SHRDON), end of pass or other operator intervention.

The LINKUP monitor will supervise the allocation of MPCC time to perform the listed functions, will cause an orderly transfer from one function to another and will test for operator intervention on each pass around the program. In addition to performing these functions in automatic the LINKUP monitor will maintain supervision over the MPCC interrupt lines so as to allow a general purpose interrupt routine (UTIRUPT) to interact with it. This is to facilitate the multiprocessor environment created by the MPCC, the Arithmetic Logic Unit (ALU) and the communications processor which must share a common data base.

4.2.1.5 STATDO Figure 4-10 - The status monitor routine is the basic system status routine. It operates on every pass of the linkup monitor to keep the machinery status current in memory. Once entered the STATDO routine may exit in only four ways; they are:

1. Emergency Shut Down (HELP).
2. Shearer Power Down (SHRDON).
3. Wait Time EXIT.
4. Normal Completion of Status Monitor.

Those functions that will cause an emergency shutdown are:

1. Methane greater than or equal to 2%.
2. CID Pressure Out of Limits.
3. CID Radiation Out of Limits.
4. CID Aperture Covers Not Properly Closed.
5. The Detection of a Fire in the System.

In each of these cases a data bit is sent to the C&D panel to set the appropriate warning indicator. No operator override capability is provided for any of these hazard monitors. There is an additional indicator (yellow) sent to the C&D panel for a methane condition greater than 1% but less than 2%. For methane levels of less than 1% a status indicator (green) is sent to the C&D panel for positive display of methane status.

Those functions which will cause a shearer power down (SHRDON) are:

1. Fire Suppression Equipment Malfunction at End of Pass.
2. Trailing Drum LCF Not Properly Stowed.
3. Trailing Drum PCF Not Properly Deployed.
4. Trailing Drum CID Not Properly Stowed.
5. Leading Drum LCF Not Properly Deployed.
6. Leading Drum CID Not Properly Deployed.
7. Leading Drum PCF Not Properly Stowed.
8. CID Current/Voltage Unsafe Limit.
9. CID Current/Voltage Intolerable Limit.
10. Face Conveyor (HEADGATE) Motor Current Limit.
11. Face Conveyor (TAILGATE) Motor Current Limit.
12. Panel Conveyor Motor Current Limit.
13. Stage Loader (RIGHT) Motor Current Limit.
14. Stage Loader (LEFT) Motor Current Limit.

The shearer power down (SHRDON) may be prevented on the first eight malfunctions listed in the above table if an operator over-ride is received before the wait timer runs out on the particular malfunction. For each of these eight malfunctions an indicator bit is sent to the C&D panel to set the appropriate indicator. On each of the last three malfunctions listed in the table above an indicator bit is sent to the C&D panel to set a warning indicator and then the routine causes a SHRDON to be executed without regard to a wait timer or possible operator over-ride.

CID voltage or current that is beyond nominal tolerance but not unsafe will cause a warning indicator (yellow) error flag to be sent to the C&D panel. If the CID voltage and current are within nominal limits a status bit will be sent to the C&D panel to illuminate a green light.

At the conclusion of the STATDO routine, program control will revert to the LINKUP monitor to determine the next execution routine in the selected mode of operation.

4.2.1.6 CALCULE Figure 4-11 - When called upon by the LINKUP monitor this routine will cause an auxiliary incrementing unit to count the CID output pulses over a programmable period of time. This integral is then transformed into floating point notation (characteristic and mantissa in two's complement binary arithmetic) and sent as four words of data to the arithmetic logic unit (ALU) as one operand. The integration time  $\tau$  is similarly transformed and sent to the ALU as the other operand. The quotient  $X_0 = \text{count} \div \tau$  is formed. This is then the count rate (normalized count value),  $X_0$ . The coal seam overburden thickness is then computed from:

$$EC = AX_0^5 + BX_0^4 + CX_0^3 + DX_0^2 + EX_0 + F$$

the ALU is used to iterate the partial sums in floating point notation. These partial sums are then summed to produce the coal seam overburden thickness EC. The constants A, B, C, D, E and F are CID calibration constants programmed into the MPCC memory by the operator through the DAS panel as part of system turn on and initialization. It is presumed at this time that the determination of these constants is performed off line. This determination is not included as part of the CALCULE routine.

In the case of the Active Nucleonic CID two different, independently suspended devices (radiation detector, radiation source), are used. Because the detector and source are independently suspended their respective distances to the idealized coal seam changes with the surface irregularities of the coal seam. The CALCULE program will be used to calculate an average distance which will be assumed to be the distance from the CID mounting platform to the coal seam surface. For the sake of simplicity this correction generation is not included in the flow chart for the CALCULE program.

At the conclusion of this subroutine, control will revert to the LINKUP monitor for a decision as to what program will execute next.

4.2.1.7 LEDRUM Figure 4-12 - This program processes the ranging arm position, sensitized pick data, CID data, coal seam thickness and mining condition according to the control algorithm for the lead drum control. The drum control law operates as follows:

1. Determine lead drum height (LDH) from known actuator extension

$$LDH = 26.38 + Rd \cdot 74.5 \sin \left[ \cos^{-1} \left( \frac{(28.32)^2 + (10.5)^2 - (23.25 - LRA)^2}{2 (28.32)(10.5)} \right) - (69.33 + 9.04) \right]$$

Where:

Rd = Cutter Drum Radius, inches

LRA = Lead Drum Ranging Arm Position

LDH = Lead Drum Height, inches

2. Determine height of last cut

$$LCSH = (LLCF + ZLC)$$

Where:

LLCF = Output of Last Cut Follower Position

ZLC = Height of Last Cut Follower Above Skid Plane

LCSH = Last Cut Seam Height

3. Determine drum height error

$$DC = |LDH - LCSH|$$

Where:

DC = Drum Height Error

LDA = Lead Drum Height

LCSH = Last Cut Seam Height

If  $|LDH - LCSH| > E$

then form following drum height command

$$LDHC = (LDSH + E \text{Sign} (LDH - LCSH))$$

4. Scale to obtain actuator drive command

$K (LDHC - LDH)$  to drive actuator.

Where:

LDSH = Lead Drum Seam Height

LCSH = Last Cut Seam Height

LDHC = Lead Drum Height Command

K = Scaling Constant

If  $|LDH - LCSH| \leq E$

5. Then go to sensitized pick for control data. If sensitized pick indicates rock then form the following drum height command:

$LDHC = (LDH - EI)$

LDHC = Lead Drum Height Command

LDH = Drum Height

EI = Error Increment as a Function of Desired Drive

6. Develop actuator drive by increments.

$DBI = |LHD - LCSH|$

If  $(DBI) \leq E$  form

$K (LHD - LDH)$  to drive actuators

If  $(DBI) > E$  then form

$LHU = LCSH + E \text{ sign } (LHD - LCSH)$

Form:  $K (LHU - LDH)$  to drive actuators

7. If sensitized pick senses rock then form:

$LHD = (LDH - EI)$

Then repeat step 6



8. If sensitized pick senses rock then form:

$$LHD = (LDH - 3EI)$$

Then repeat step 6.

9. If sensitized pick indicates coal then form:

$$LHU = (LDH + EI)$$

form

$$LHU - LCSH$$

If  $(LHU - LCSH) \leq E$  then form  $K = LHU - LDH$

and drive actuators

If:  $(LHU - LCSH) > E$  then form

$$LHD = LDH + E \text{ sign } (LHU - LDH)$$

Form:  $K = (LHD - LDH)$  and drive actuators

10. Examine sensitized pick, if it indicates coal repeat step 8.

11. If sensitized pick indicates rock go to step 5.

12. If sensitized pick indicates coal and there has been a head coal setting at the Control & Display Console of something other than zero the CID is monitored to determine coal thickness. The flow chart begins with a summation of the algorithm required for determining coal thickness or depth. This coal depth is given a MNEMONIC of (CD). An expansion of this portion of the LEDRUM flow diagram was performed and can be reviewed in the CALCULE flow diagram, Figure 4-11, where the coal thickness is referred to as Ec.

The relative position sensor is then read which relates the height of CID relative to its machine base.

13. Form the following height command.

$$LDC = RDH + RP + CD - HTS$$

Where:

$$LDC = \text{Lead Drum Command}$$

RDH = Height of CID above mounting base skid plane

RP = Height of CID relative to mounting base

CD = Coal thickness measurement (Coal Depth)

HTS = Head Thickness Setting (Amount of coal to be left)

14. Form  $|LDC - LCSH|$

If  $|LDC - LCSH| \leq E$  form LHU command

If  $|LDC - LCSH| > E$  form LHD command

Drive actuators

Repeat 1

This calculation will be performed and the control commands executed when requested by the LINKUP monitor. At the conclusion of the LEDRUM routine control will revert to the LINKUP monitor for a decision as to what program will execute next.

4.2.1.8 TRADRUM Figure 4-13 - This routine processes the present cut follower and cut height input data to determine the position of the bottom drum cut. This drum control law acts as follows:

1. Let PCF = Present Cut Height

2. Form:

$$TDH = 26.38 - Rd + 74.5 \sin \left[ \cos^{-1} \left( \frac{(128.32)^2 + (10.5)^2 - (23.25 + TRA)^2}{2(28.32 \times 10.5)} \right) - (69.33 + 4.04) \right]$$

TDH = Bottom Drum Height, inches

Rd = Bottom Drum Radius, inches

TRA = Actuator Extension, inches

3. Form the drum elevation command:

$K (STS - PCF + TRA)$  to drive actuators

Where:

**K = Scaling Constant**

**STS = Seam Thickness Setting**

**PCF - Present Cut Follower**

**TRH - Bottom Drum Controlled Height**

After output command has been initiated to drive actuators the bottom drum sensitized pick is read to determine if the bottom drum is into coal or rock. This information is sent to the C&D panel for display. At the conclusion of this subroutine control will revert to LINKUP for the next programmed routine.

**4.2.1.9 ROLRAM** Figure 4-5 . The ROLRAM routine processes the angular data from the inclinometer and the seam inclination parameter programmed from the C&D panel to develop correction data to the roll ram actuator.

There are two different methods under consideration for controlling the angle of the shearer about its longitudinal axis. These methods are:

1. Include the inclinometer in the control loop to the actuator thereby eliminating a position encoder on the actuator ram.

2. Drive the position loop servo on the actuator externally with the seam inclination parameter and with the inclinometer output at its input summing junction. This method requires position feedback (encoder) data to be developed by the roll ram actuator.

Simulation results indicate that both implementations yield essentially the same results. Hence for simplicity method #1 has been assumed in the present design and is outlined below.

**Form:**

$$YE = (YCC - YSI)$$

**Where:**

**YE = Inclination Error**

**YCC = Inclinometer Output Error**

**YSI = Seam Inclination Parameter**

**Test YE to determine magnitudes.**

If  $YE > E$  then form actuator drive so:

$$YC = -kYE$$

$YC$  = Correction Drive to Actuator

$k$  = Scaling Constant

$YE$  = Roll Ram Inclination Error

This correction routine will operate when ever called upon by LINKUP routine. When the correction has been sent to the actuator contro' will revert to LINKUP for the next sequential program.

The second method of roll ram control (not shown in flow chart form) is the classic position loop (Figure 4-17) for completeness. Trade offs between cost, performance, reliability and maintainability are not complete at this time. However it is clear that either of the two methods may readily be implemented under control of the LINKUP monitor with the microprocessor system described.

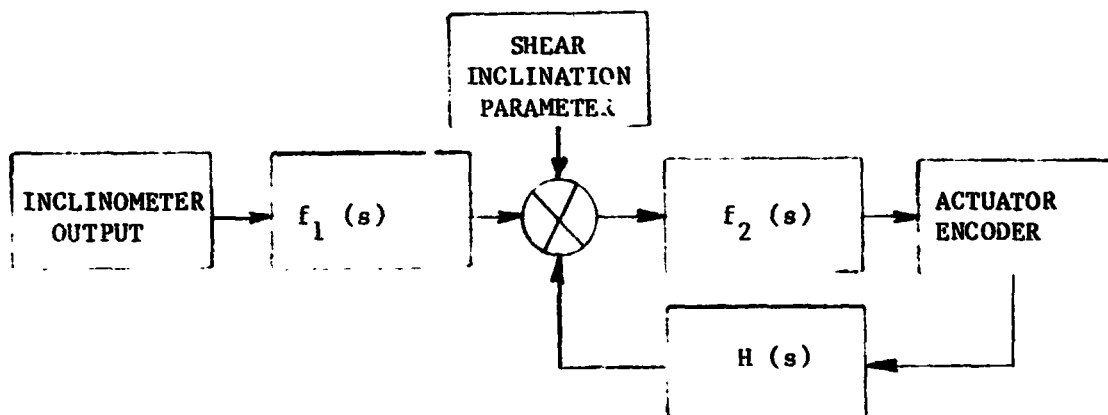


Figure 4-17. Roll Ram Position Servo Loop

4.2.1.10 SHROND Figure 4-15 - When the shearer gets to the end of a pass during the normal coal cutting operation the LINKUP monitor senses this condition and initiates the SHROND routine. The SHROND routine is designed to provide an assist to an essentially manual turn around procedure.

When the shearer arrives at the end of a pass it stops the haulage motor and waits for operator intervention. Since the times involved in awaiting operator intervention are long compared to the

execution times involved in the assist operation, the MPCC will spend most of its time under control of the LINKUP program executing the ROOFUP program. ROOFUP is a calculation program whose function is to calculate the correction data to be supplied to the roof supports for system yaw alignment. Details of this program are not included in this report. From time to time the act of manual intervention will interrupt this activity in order to obtain the assist to the turn around sequence.

The first operator intervention is to establish voice communications between the tailgate operator and the C&D operator on the C&D panel. The operator at the C&D panel turns the haulage motor speed to zero and examines the status display to assure it is ready for turn around.

When all is ready for turn around the following, individually operator initiated, sequence of events is started.

1. Stow Leading Drum Cut Follower
2. Stow Leading Drum CID
3. Lower Lead Ranging Arm
4. Set Leading Drum Cowl Position
5. Stow Trailing Drum Cut Follower
6. Set Trailing Drum Cowl Position
7. Raise Trailing Drum Ranging Arm
8. Deploy Cut Follower
9. Deploy the CID

As each step proceeds in this sequence it is visually observed by the operator on the headgate or tailgate end of the communications link.

Certain of the remotely initiated steps in this sequence are program assisted because they involve a mechanical sequence whose individual steps do not have individual controls. These steps are, (Reference list above):

Item 2. Stow Leading Drum CID

- (A) Retract CID Deployment Cylinder
- (B) Retract CID Stowage Mechanism

**Item 3. Lower Lead Drum Ranging Arm**

- (A) Lower Ranging Arm
- (B) Extend Support Cylinder

**Item 4. Set Leading Drum Cowl Position**

- (A) Set Cowl Position
- (B) Retract Swing Arm Cylinder
- (C) Deploy Cut Follower Rotary Actuator

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**Item 5. Stow Trailing Drum Cut Follower**

- (A) Place Rotary Actuator in Stow Position
- (B) Extend Swing Arm Cylinder

**Item 6. Set Trailing Drum Cowl Position**

- (A) Set Cowl Position
- (B) Retract Support Cylinder

**Item 7. Raise Trailing Drum Ranging Arm**

- (A) Raise Ranging Arm
- (B) Deploy Cut Follower

**Item 8. Deploy CID**

- (A) Extend CID Stowage Mechanism
- (B) Extend CID Deployment Cylinder

At the conclusion of this sequence the shearer turn around status is examined for proper insertion of the traverse direction command and then haulage motor speed is increased (remotely) to the desired haulage speed. The control of the system will then revert to LINKUP and the automatic sequence may continue. During this sequence the ROOFUP routine, on a time shared interrupt basis, has calculated the roof support yaw alignment correction data and sent it to the individual roof supports so the face conveyor is in proper position for initiating a new cut.

4.2.1.11 LINKUP Monitor in Remote Mode Figure 4-3 - In the remote mode of operation a minimum of MPCC assistance is provided in the execution of commands. The MPCC under the LINKUP monitor will cause the system to exercise the status monitoring routine (STATDO), to monitor interrupt and condition flags for the purpose of mode switching and it will monitor the remote C&D panel to secure individual instructions from the buttons.

The control, at the C&D panel, will cause discrete commands to be entered into the MPCC memory for execution under the LINKUP program.

When the DAS control panel is enabled by key switch the remote mode of operation will allow a broad range of instruction entry and status determination through the DAS keyboard at the C&D panel.

4.2.1.12 STATDO Under Remote Operation Figure 4-10 - The status monitor program STATDO will monitor status and send status and warning flags to the C&D panel in the same manner as it does for the automatic mode of operation. This routine will also access the HELP and SHRDON power down routines. In this mode of operation the status monitor will contain the same wait time exits that it used for the automatic mode and the linkup program may assign the MPCC other work in the system while waiting for operator intervention.

4.2.1.13 Remote Panel Operations - The discrete remote panel operations available to the operator are as listed in Table 4-5. MPCC assist for each of these remote functions is provided. Each push button command results in a primitive order in a specified memory location. Each such primitive order is expanded in a macro under LINKUP control to cause the commanded action to occur.

The following parametric data for system operation may be entered at the C&D panel.

1. Cut Height
2. Seam Thickness
3. Coal Bias
4. Difference between two successive cuts
5. Seam Inclination
6. Direction of Travel
7. Haulage Rate

4.2.1.14 Digital Address System (DAS) - All command and control information in the system is sent to the control microprocessor memory in the form of two character hexadecimal words. The DAS keyboard provides for the reading and/or modifying of this data base in memory one word at a time. When used for discrete control it provides access to the same data base that the MPCC accesses. This is very useful for purposes of diagnosing system malfunctions either mechanical or

**Table 4-5. List of Discrete Remote Functions**

MAIN POWER ON/OFF  
EMERGENCY POWER OFF  
FIRE SYSTEM ON/OFF  
AUTOMATIC MODE  
LOCAL MODE  
REMOTE MODE  
HYDRAULIC PUMP START/STOP  
RIGHT CUTTER MOTOR START/STOP  
LEFT CUTTER MOTOR START/STOP  
LEFT COWL RAISE/LOWER  
RIGHT COWL RAISE/LOWER  
HAULAGE RATE  
RIGHT CUTTER RAISE/LOWER  
LEFT CUTTER RAISE/LOWER  
LEFT CID STOW/DEPLOY  
RIGHT CID STOW/DEPLOY  
LEFT CUT FOLLOWER STOW/DEPLOY  
RIGHT CUT FOLLOWER STOW/DEPLOY  
INTERCHANGE CUT FOLLOWERS  
ROLL RAM TILT INCREASE/DECREASE



electrical in nature. This same DAS panel may be used to access all status and error flags in memory and to display them to the operator for study.

The DAS panel may be accessed in the remote mode by the use of a key switch only.

4.2.1.15 Linkup Monitor in Manual Mode Figure 4-3 - In the manual mode of operation the MPCC will operate to execute STATDO, and MACSEQ routines. Display status will be presented to the C&D panel through the normal communications link. In the manual mode of operation the manual control panel has control of the following functions:

1. Pre-emptory Mode Control
2. Right Ranging Arm Raise/Lower
3. Left Ranging Arm Raise/Lower
4. Right Cowl Forward/Reverse
5. Left Cowl Forward/Reverse
6. Cutter Motors Start/Run/Off
7. Haulage Motor Forward/Reverse
8. Haulage Motor Speed Control
9. Hydraulic Pump Start/Run/Off
10. Power On/Off

A methane monitor function is also included on the manual panel. All of the STATDO monitored functions (see section 4.2.1.5) are sent to the C&D panel for remote display in this mode of operation. The LINKUP monitor in manual mode will be evoked whenever a manual button is depressed or a key is removed at the headgate or tailgate.

4.2.1.16 STATDO Figure 4-10 - In the local mode of operation the status monitor program STATDO operates to monitor status in the same way as it does for the automatic and remote modes of operation. (see sections 4.2.1.5 and 4.2.1.12).

4.2.1.17 MACSEQ Figure 4-16 - In the manual mode the MACSEQ routine is called to perform the following functions:

1. Stow Coal Interface Detectors (CID)

2. Stow Last Cut Followers (LCF)
3. Stow Present Cut Followers (PCF)

Two indicator bits are sent to memory for use by the remote C&D panel. They are:

1. Store CID Disable Command
2. Store Manual Light Indicator Flag

To exit the manual mode another mode must be selected and the system constraints for that mode must be satisfied.

4.2.1.18 Power Down Sequences - Three ways of powering down the system under the LINKUP monitor exist, they are:

Emergency Power Down (HELP)

Shearer Power Down (SHRDON)

Normal Power Down (PWRDON)

4.2.1.19 HELP Figure 4-7 - When the HELP routine is triggered the linkup monitor has been informed of a hazardous mining condition. The main power to the equipment is disconnected without delay. The system may be restarted by going through the entire restart sequence including reloading the volatile microprocessor memory banks in the system.

4.2.1.20 SHRDON Figure 4-8 - When the SHRDON routine is triggered the LINKUP monitor has been informed of a malfunction in the shearer. The SHRDON program sequences the shearer off according to the following schedule:

1. Sound Audible Alarm
2. Stop Cutter Motors
3. Stop Haulage Motor
4. Wait Time 2 Minutes
5. Stop Shearer Water

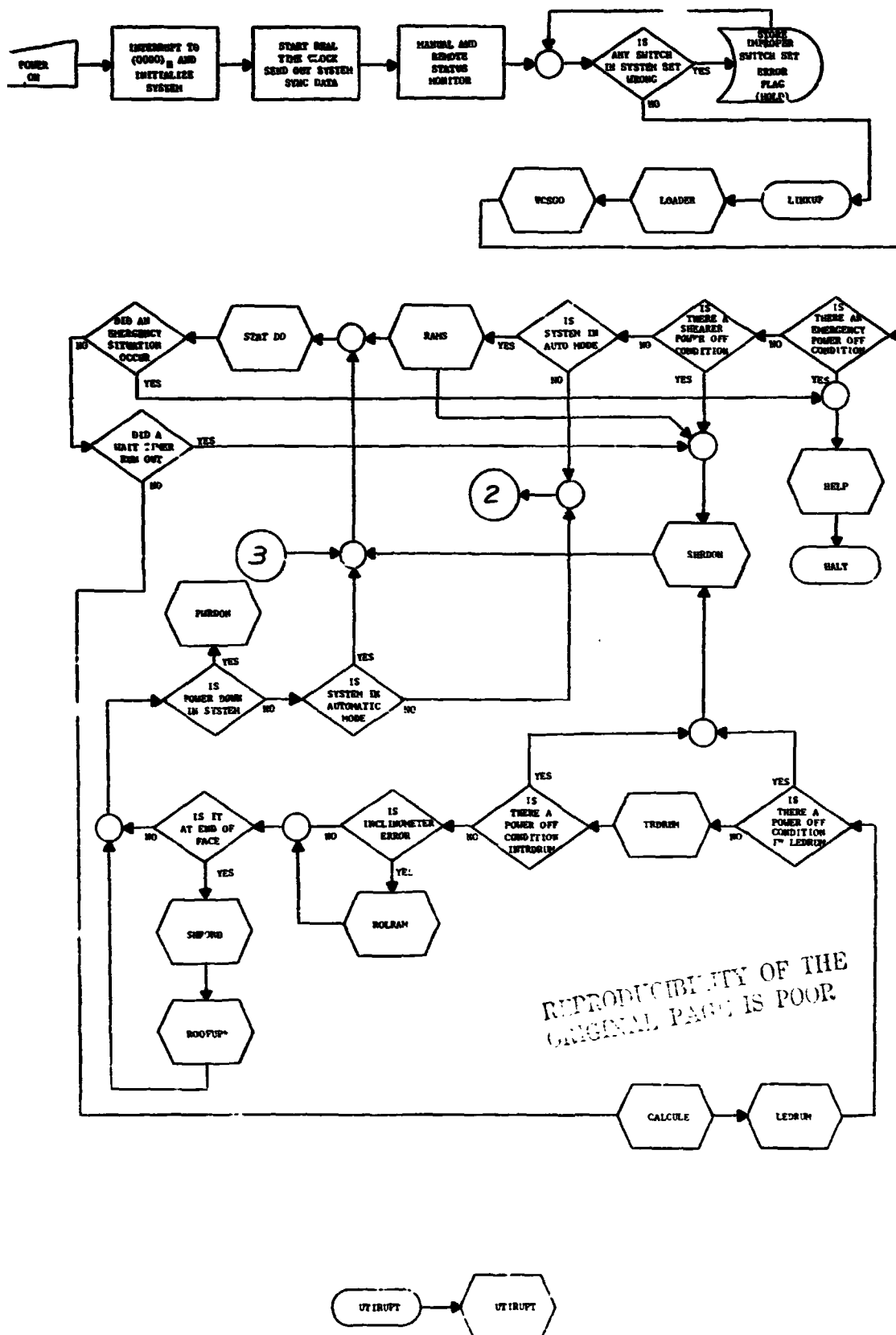
At the conclusion of the SHRDON routine the system reverts to the STATGO monitor program for system status monitoring. The system may be restarted by depressing the power "on" switch after the malfunction has been cleared or repaired.

4.2.1.21 PWRDON Figure 4-14 - This is a normal power down sequence conducted under the LINKUP monitor. The steps to the sequence are as shown below:

1. Stop Haulage Motor
2. Stop Cutter Motor #1
3. Stop Cutter Motor #2
4. Stop Active CID
5. Stop Last Cut Follower
6. Stop Present Cut Follower
7. Stop Face Conveyor #1
8. Stop Face Conveyor #2
9. Stop Panel Conveyor Motor
10. Stop Stage Loader Motor #1
11. Stop Stage Loader Motor #2
12. Turn Off Shearer Hydraulic Pump
13. Wait Time 2 Minutes
14. Turn Off Shearer Water

4.2.2 Hardware Requirements - The hardware requirements, as determined from the preceding operational flow diagrams and descriptions are as shown in the main processing and control computer block diagrams, Figure 4-19. This hardware is based upon a CMOS microprocessor. As noted in previous sections, the CMOS technology was chosen because of its low power consumption, which is important in intrinsically safe electronic circuits. Another reason for the chosen technology is that of its high reliability which was a primary reason for its development. This technology also has one of the highest noise immunities available for logic circuits both from power line noise and signal noise.

The microprocessor family chosen is that of the 1800 series manufactured by RCA and Hughes through some cross licensing on microprocessor and related technologies. The CMOS logic family chosen is that of the 4000 series manufactured by RCA, Motorola and others.



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Figure 4-3. Master Monitor Program (LINKUP)  
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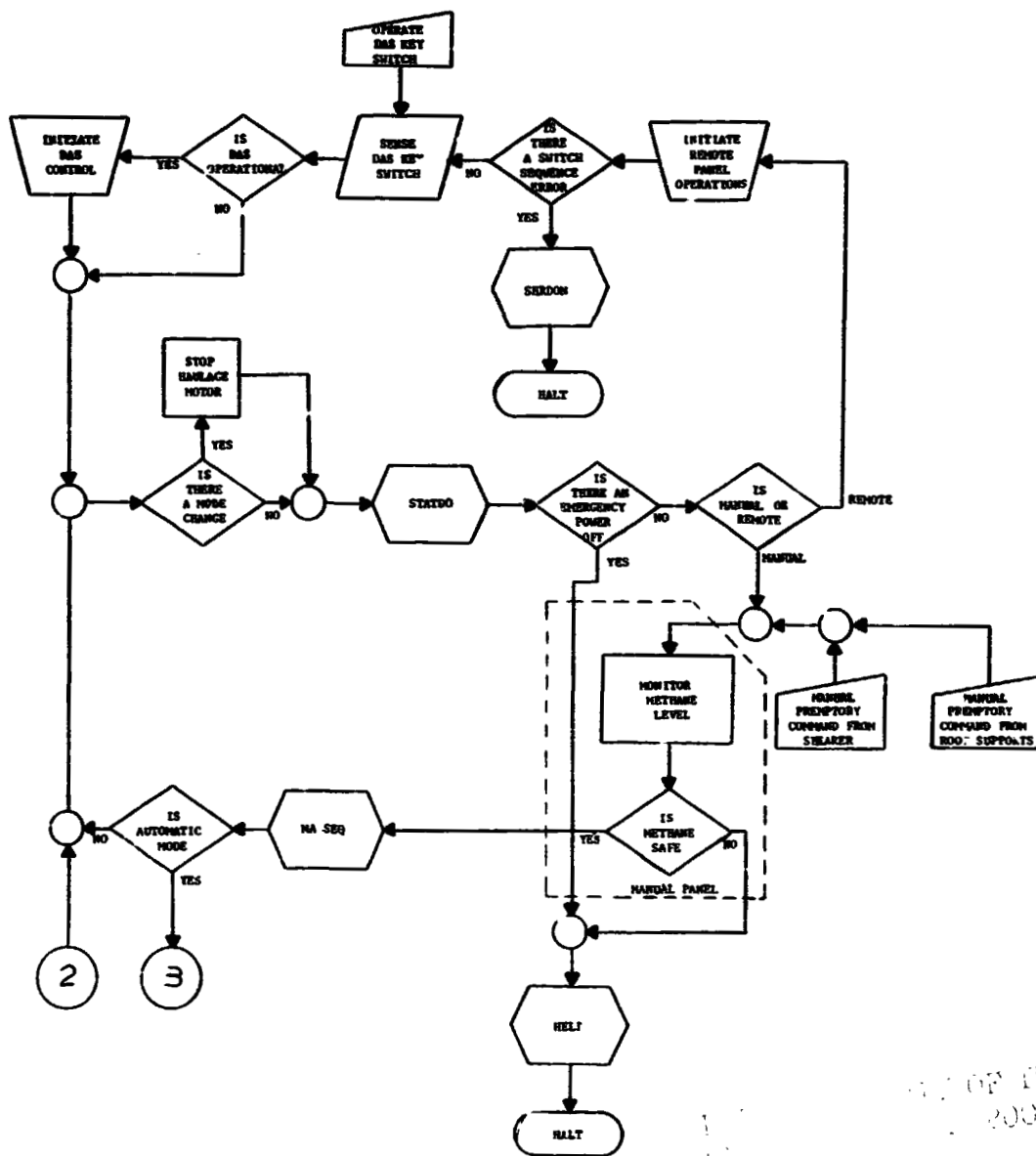


Figure 4-3. Master Monitor Program (LINKUP)  
(Page 2 of 2)

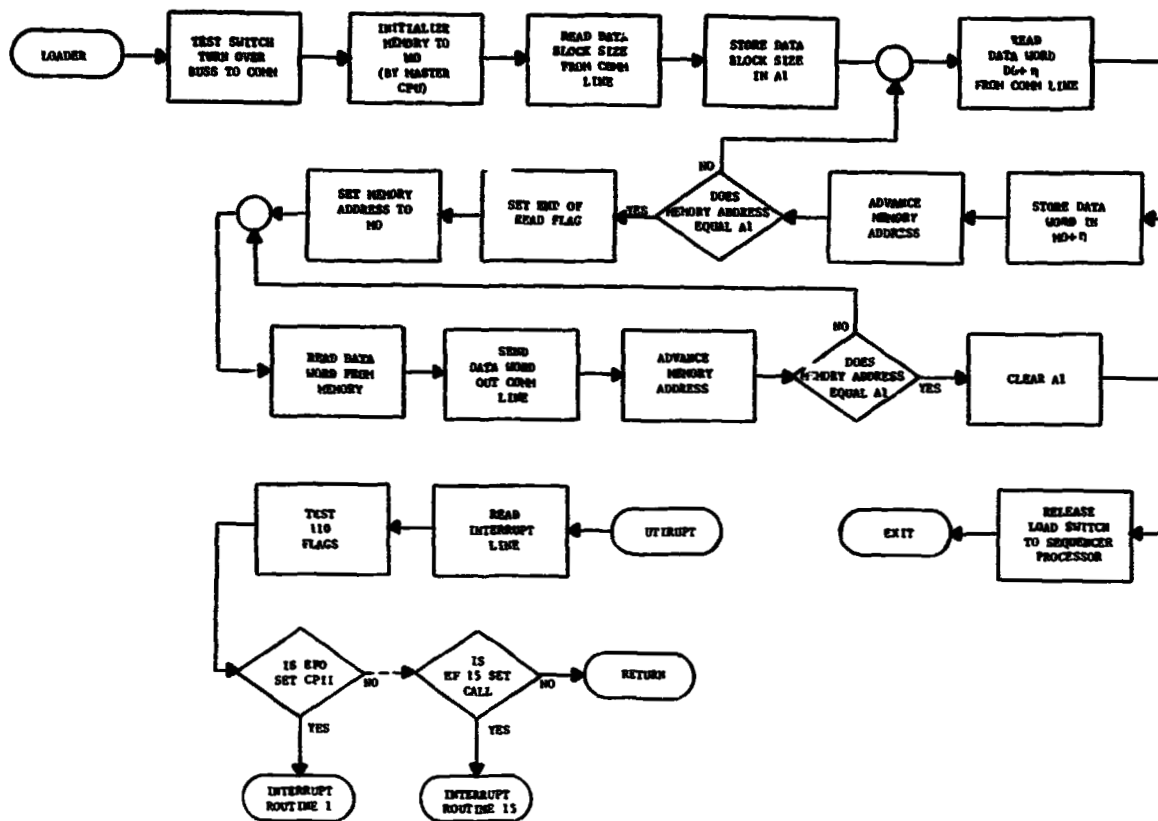


Figure 4-4. Parametric Data Loader at Turn On (LOADER)

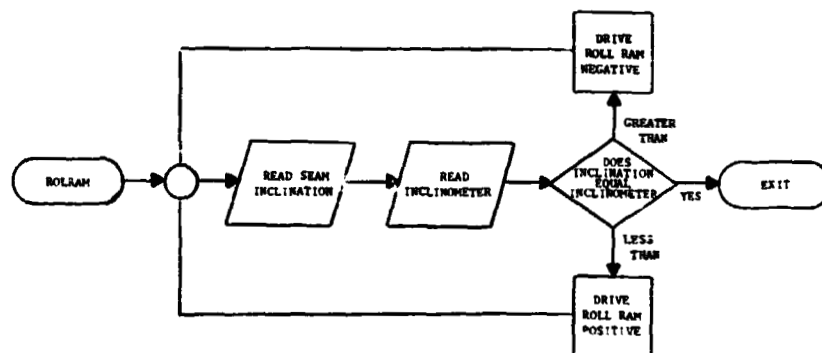


Figure 4-5. Roll Ram Control Algorithm (ROLRAM)

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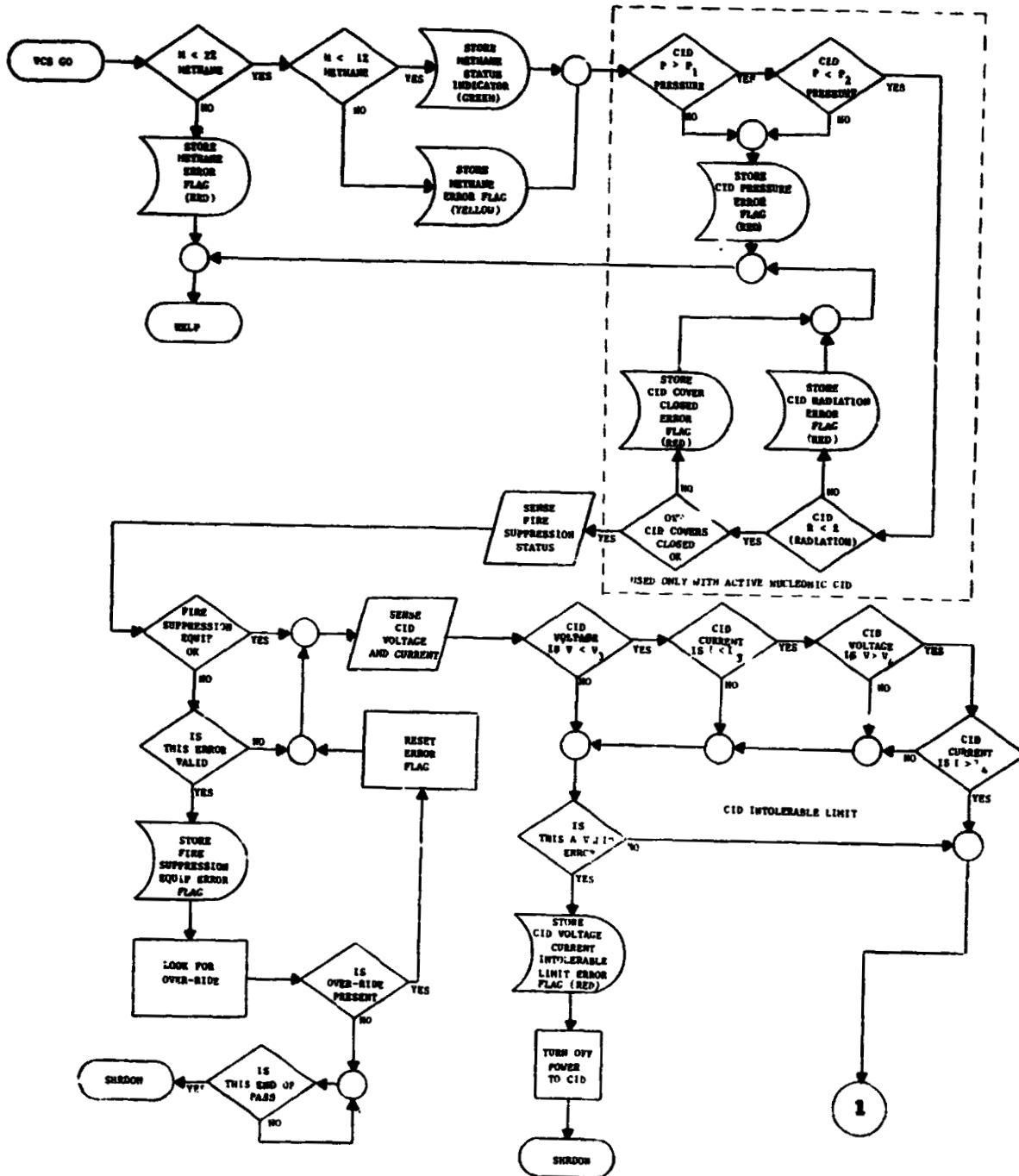
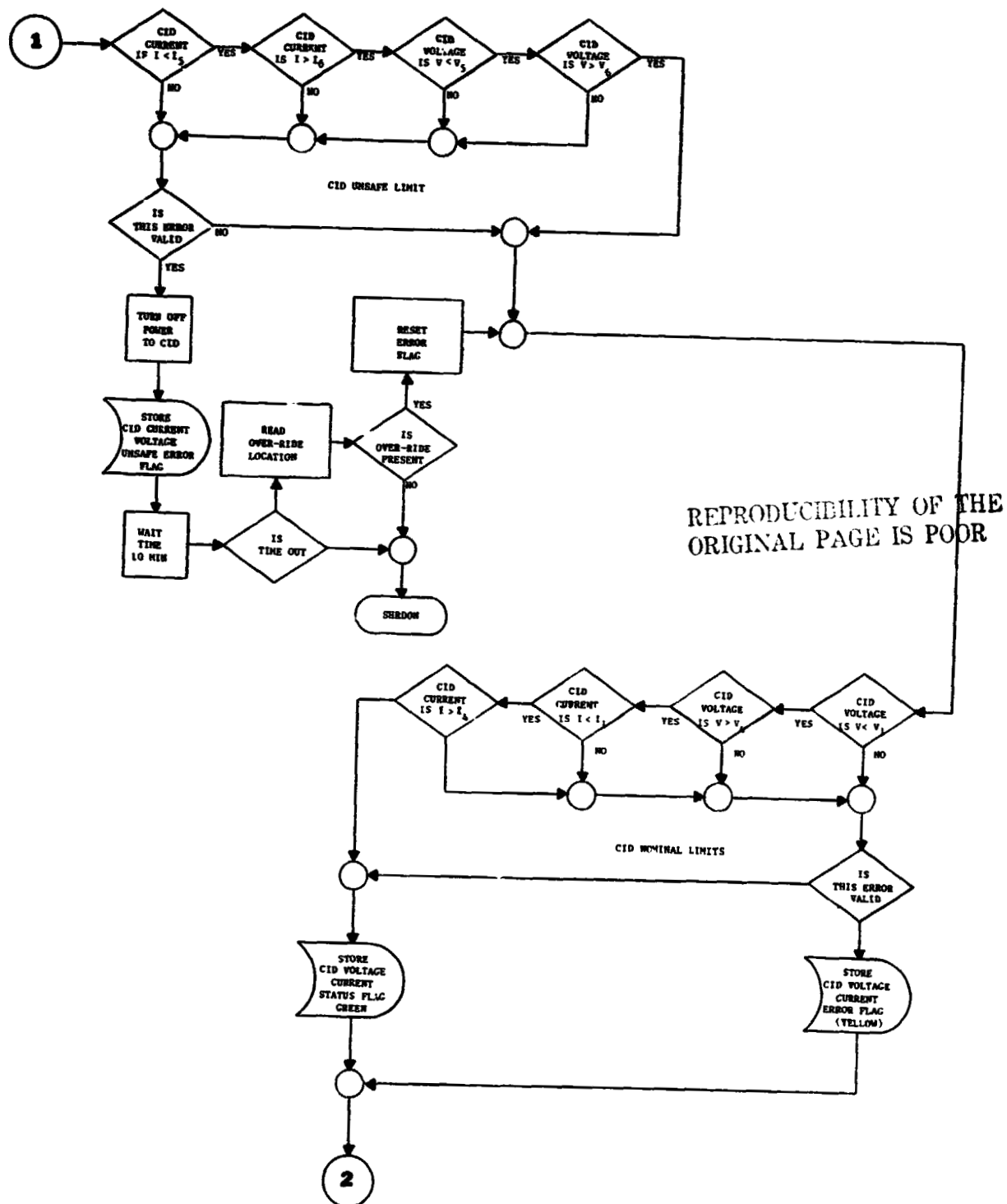


Figure 4-6. VCS Turn On Procedure (VCSGO)  
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Figure 4-6. VCS Turn On Procedure (VCSGO)  
(Page 2 of 3)



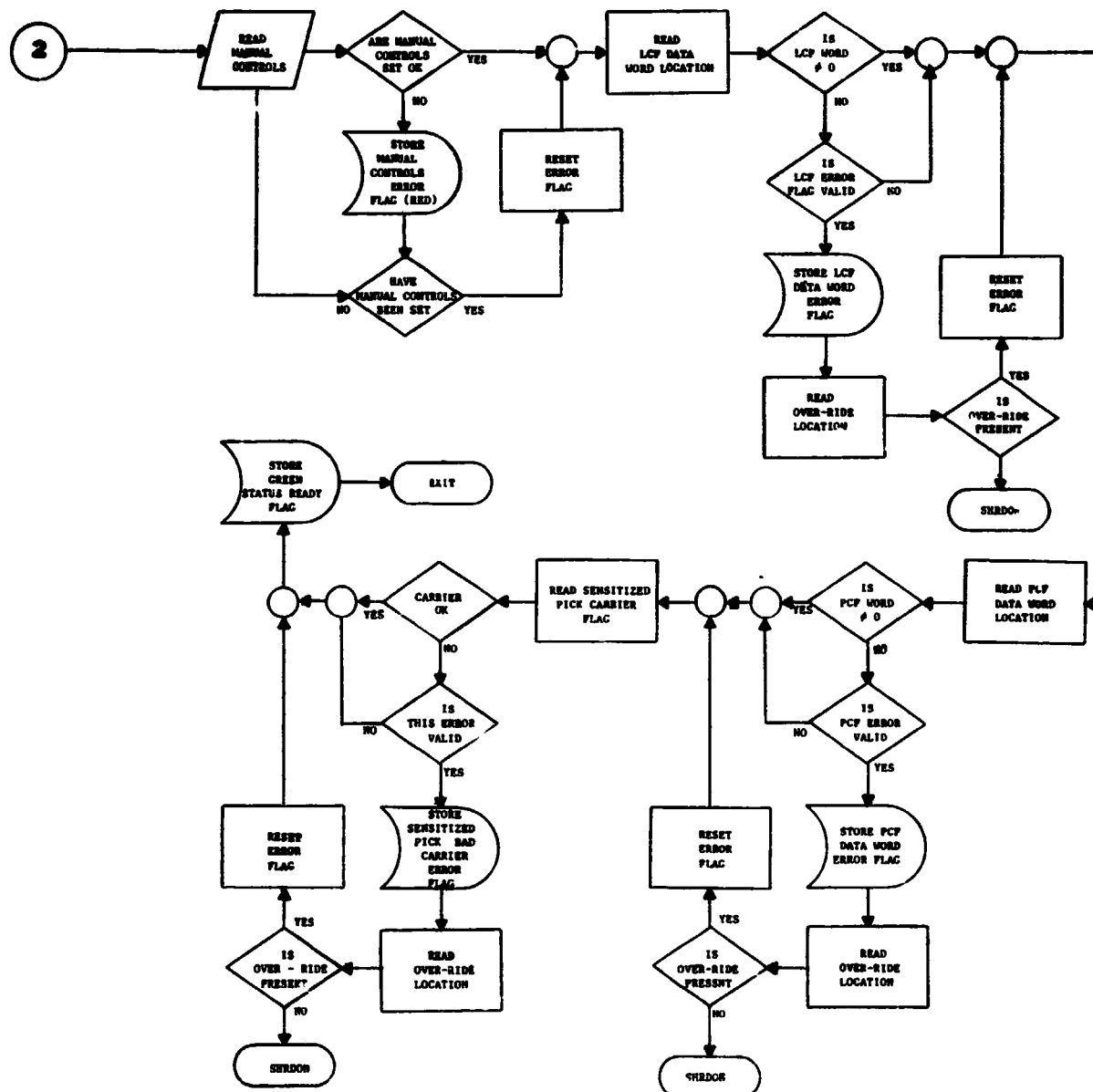


Figure 4-6. VCS Turn On Procedure (VCSG0)  
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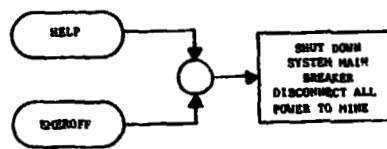


Figure 4-7. Emergency Shutdown (HELP)



Figure 4-8. Malfunction Shearer Power Off (SHRDON)

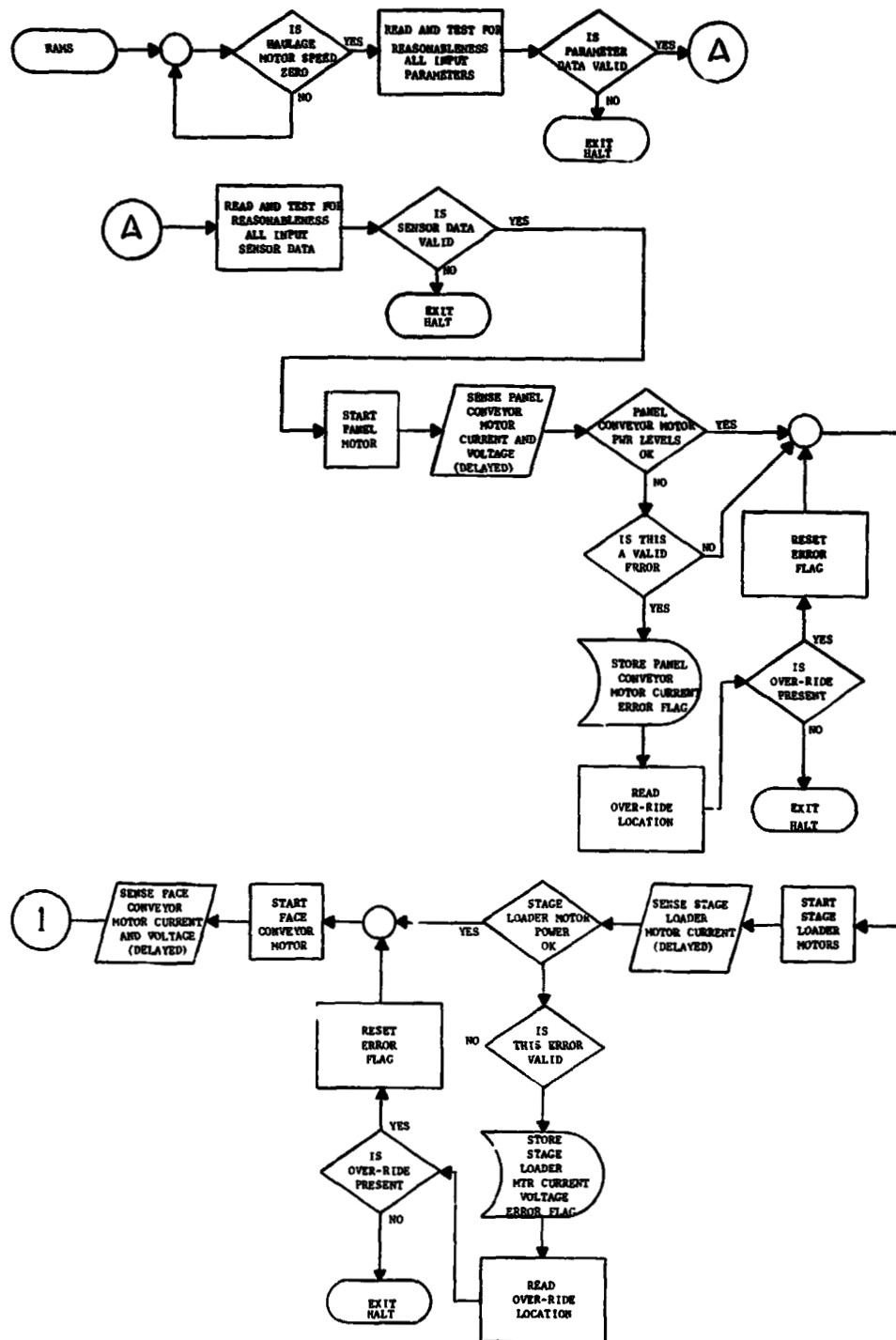


Figure 4-9. Remote Automatic Mode Sequence On (RAMS)  
(Page 1 of 7)

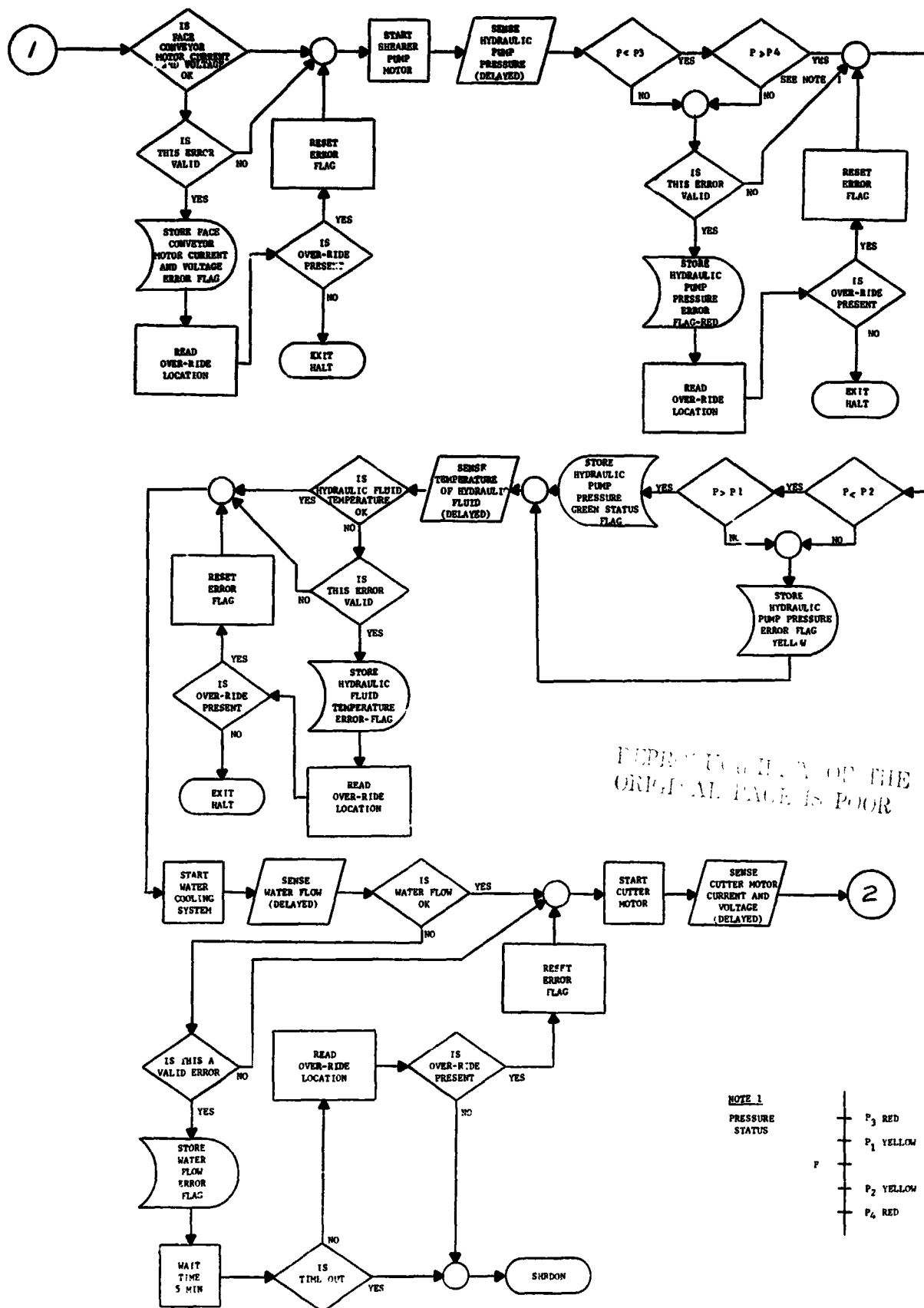


Figure 4-9. Remote Automatic Mode Sequence On (RAMS)  
(Page 2 of 7)

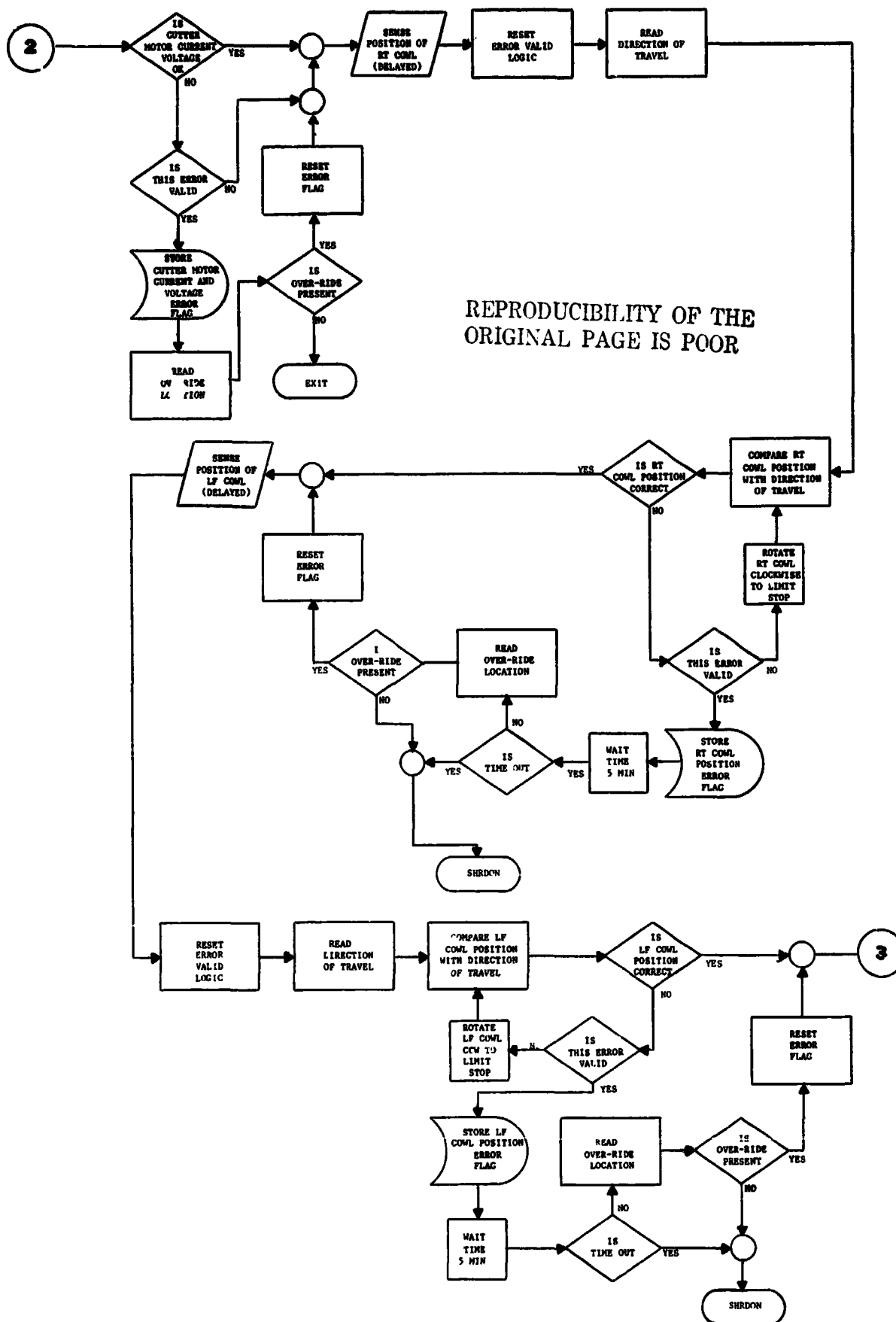


Figure 4-9. Remote Automatic Mode Sequence On (RAMS)  
(Page 3 of 7)

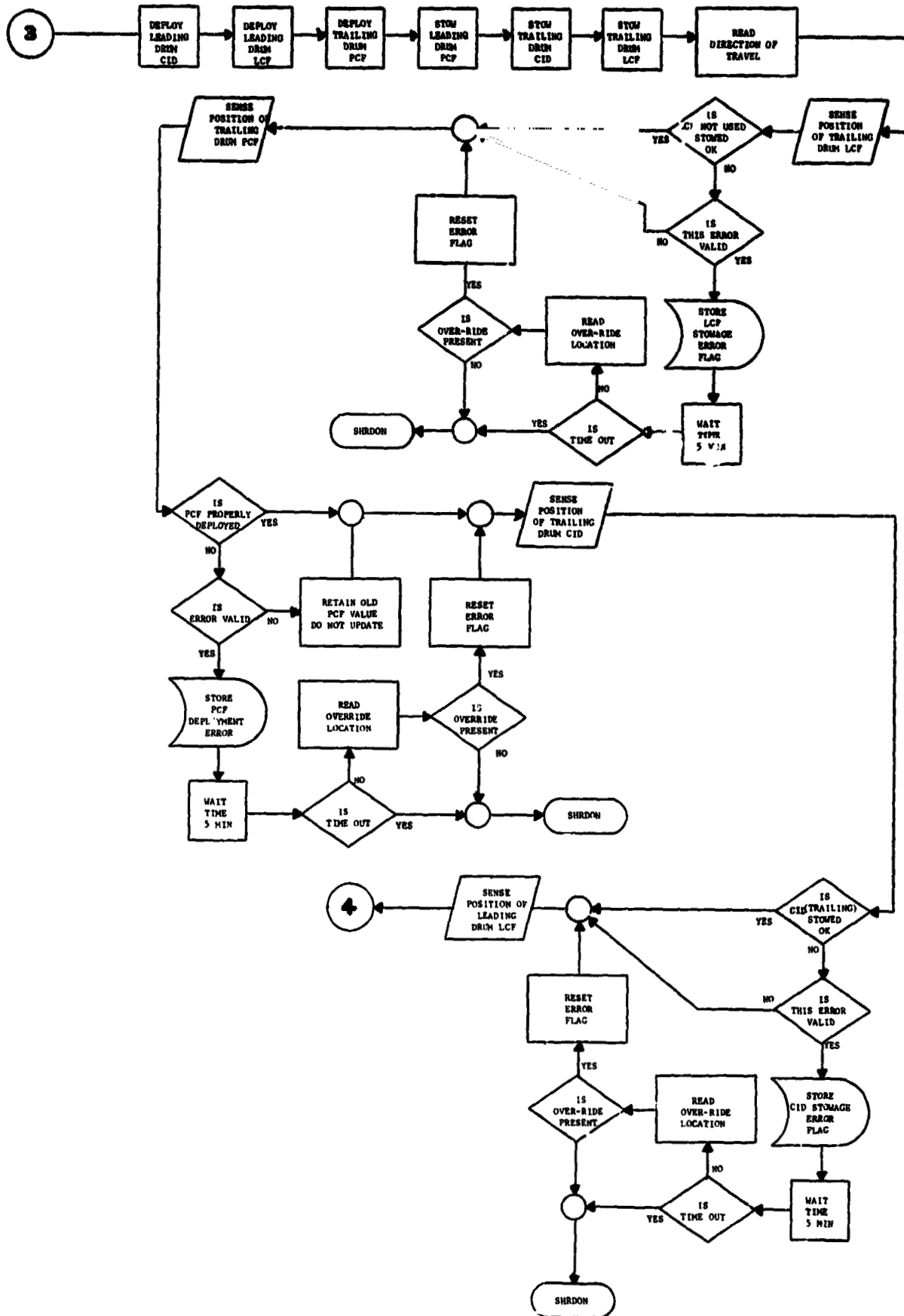


Figure 4-9. Remote Automatic Mode Sequence On (RAMS)  
(Page 4 of 7)

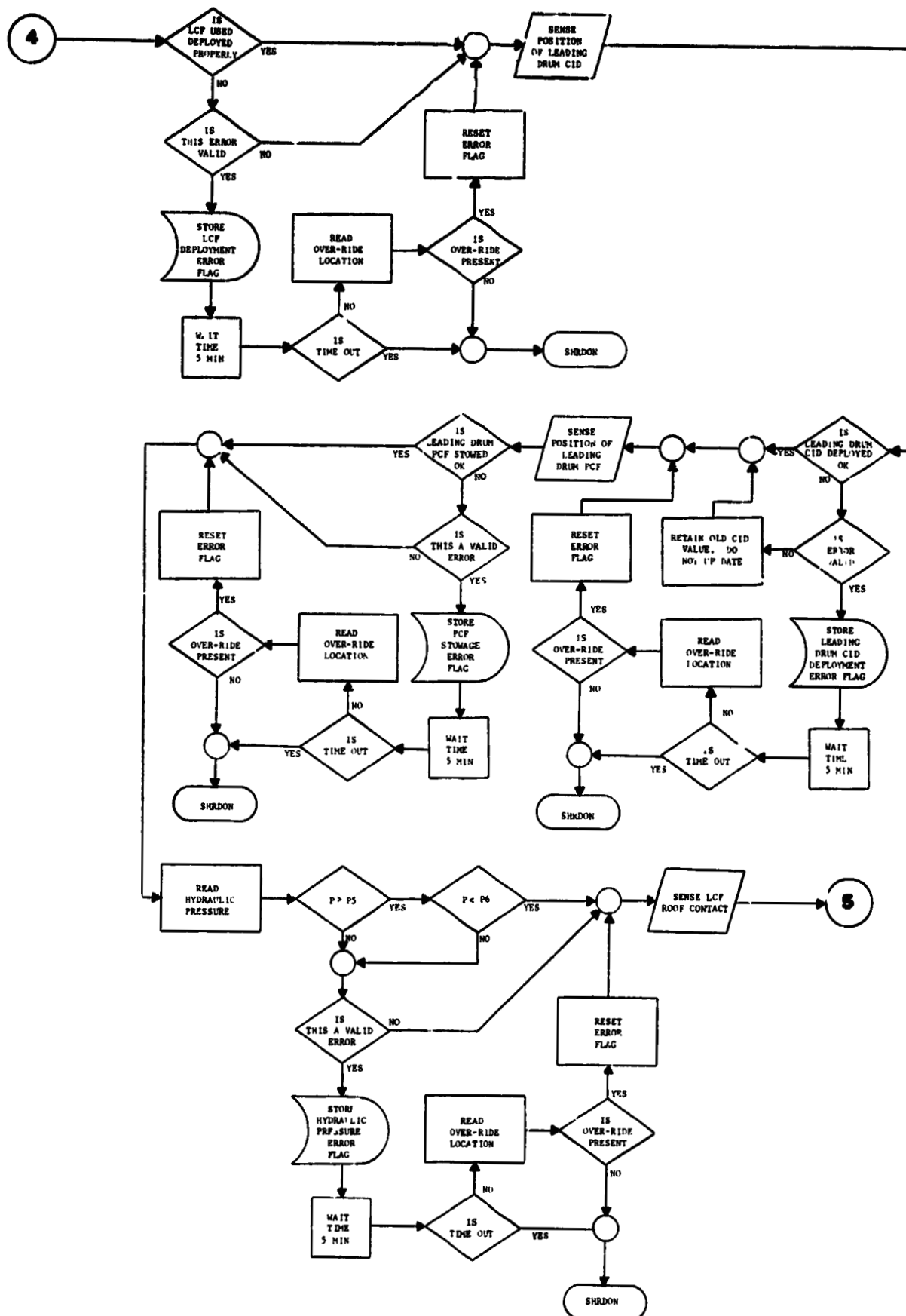


Figure 4-9. Remote Automatic Mode Sequence On (RAMS)  
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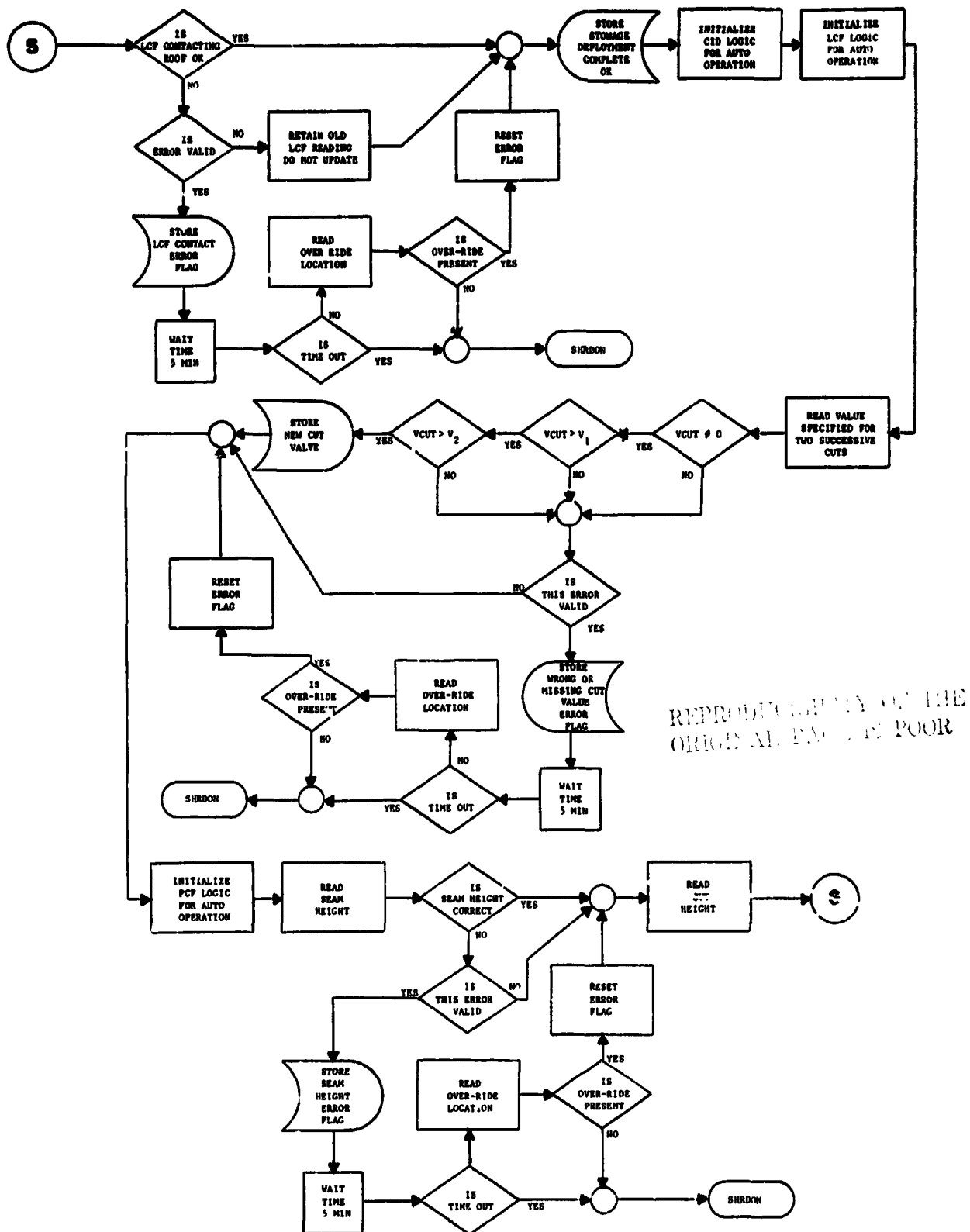


Figure 4-9. Remote Automatic Mode Sequence On (RAMS)  
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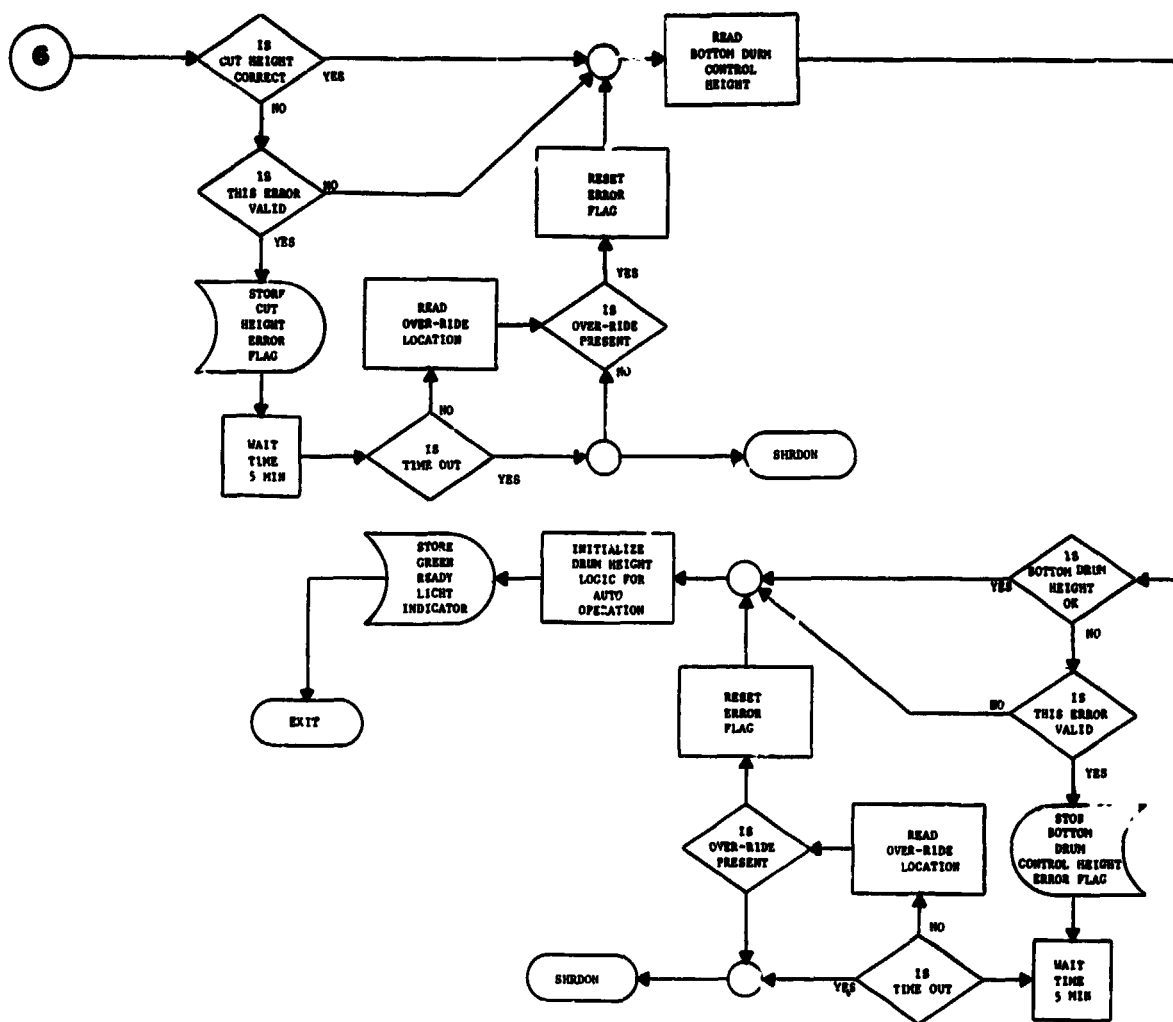


Figure 4-9. Remote Automatic Mode Sequence (RAMS)  
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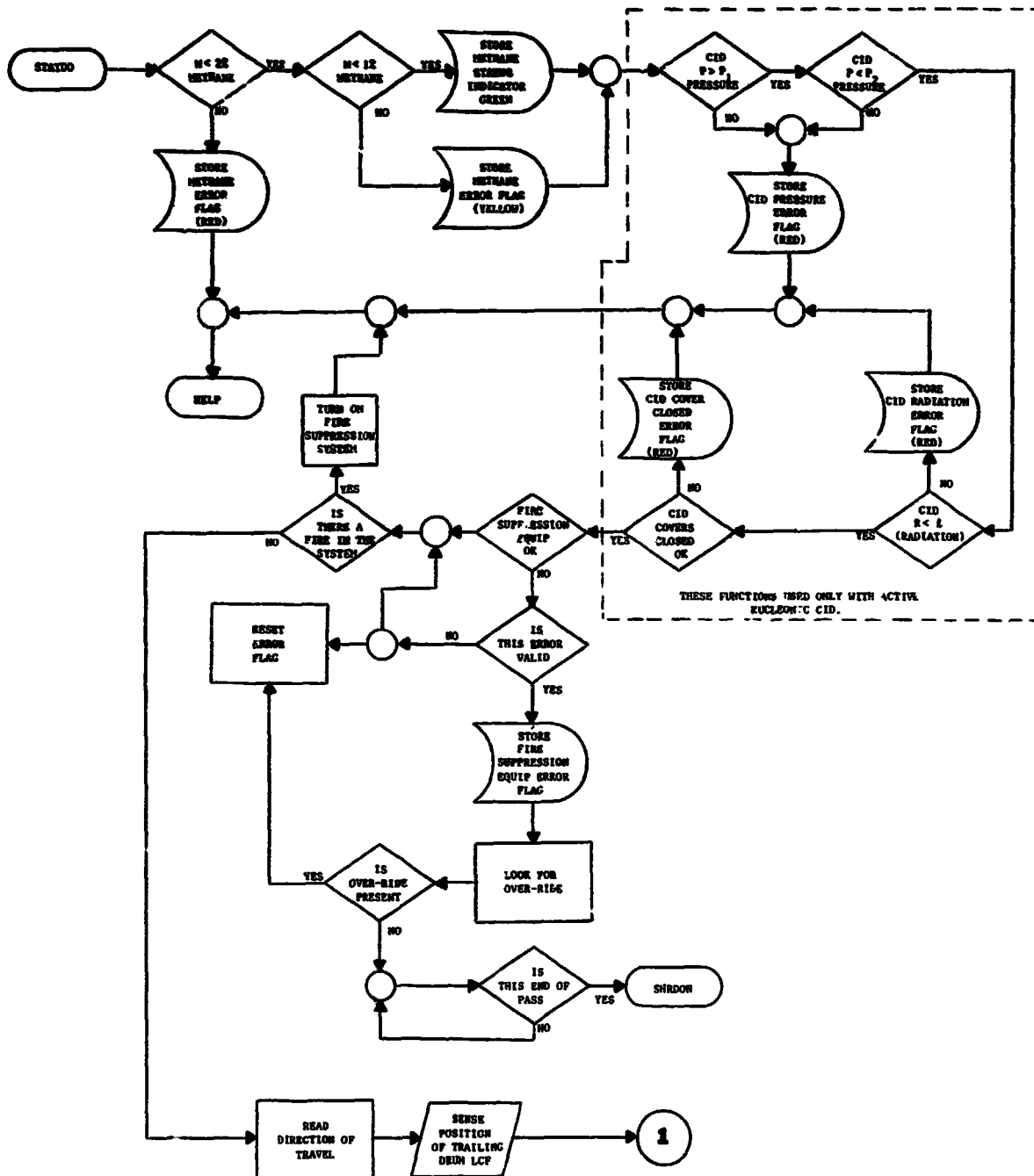


Figure 4-10. Status Monitor (STATDO)  
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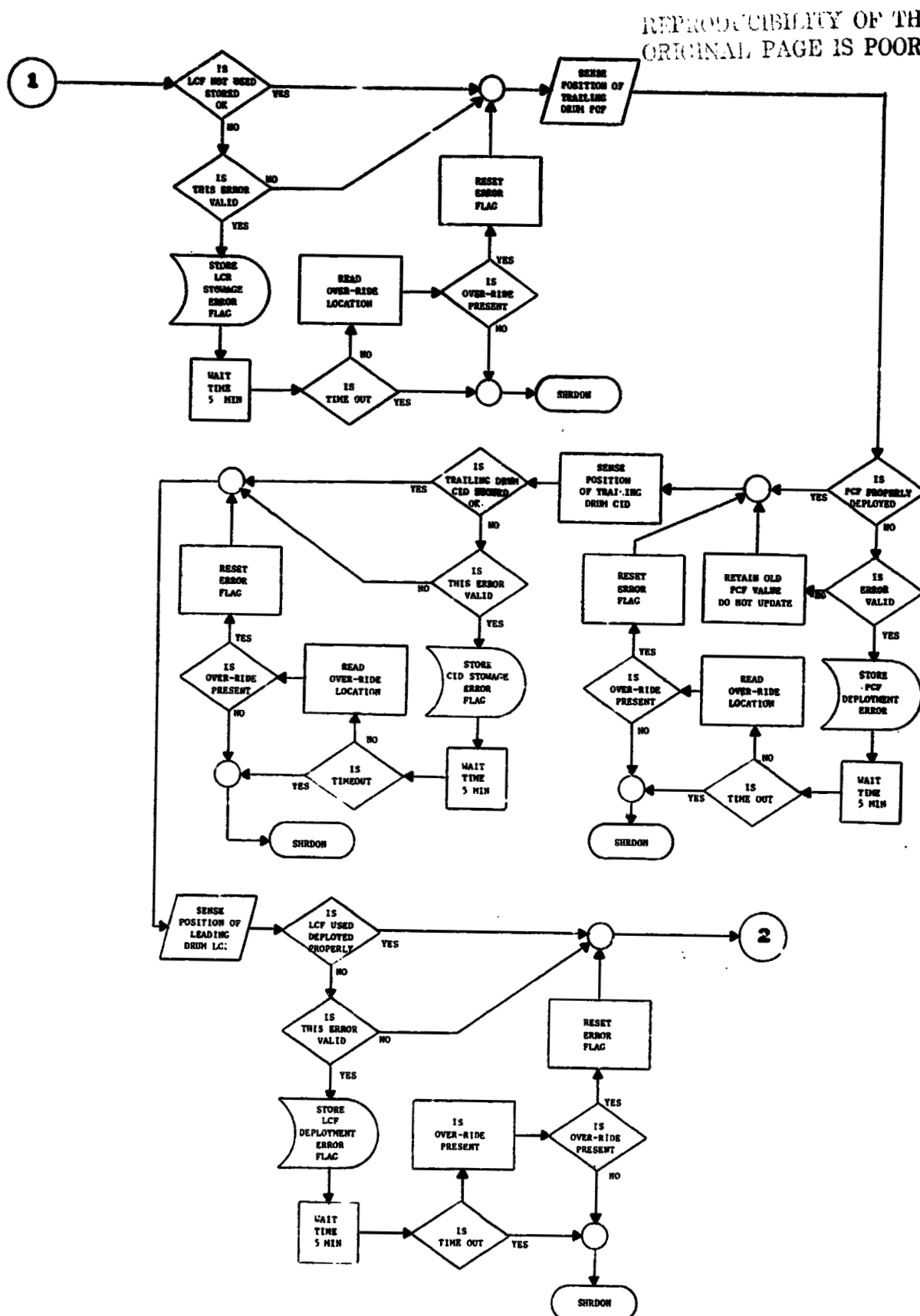


Figure 4-10. Status Monitor (STATDO)  
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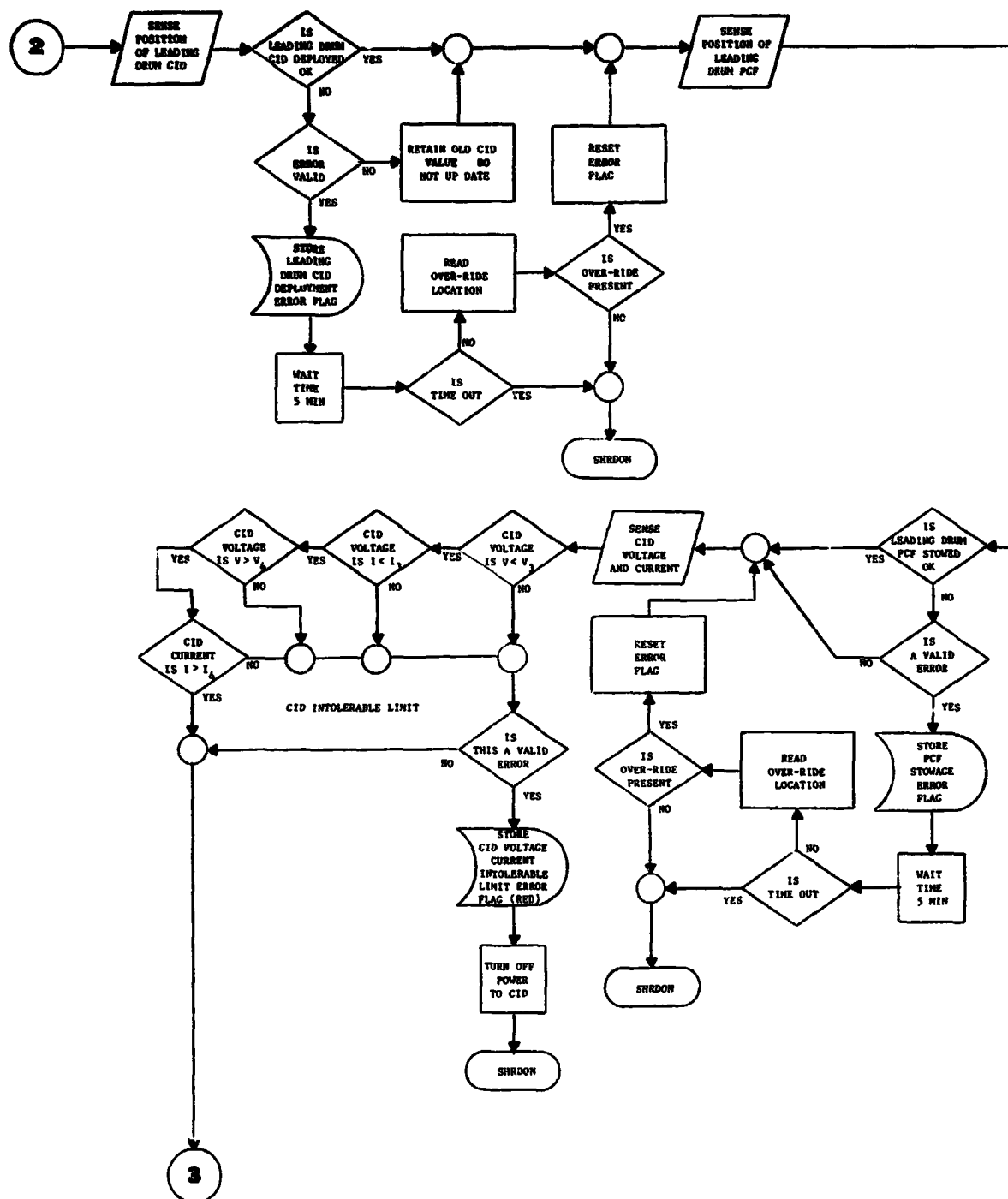


Figure 4-10. Status Monitor (STATDO)  
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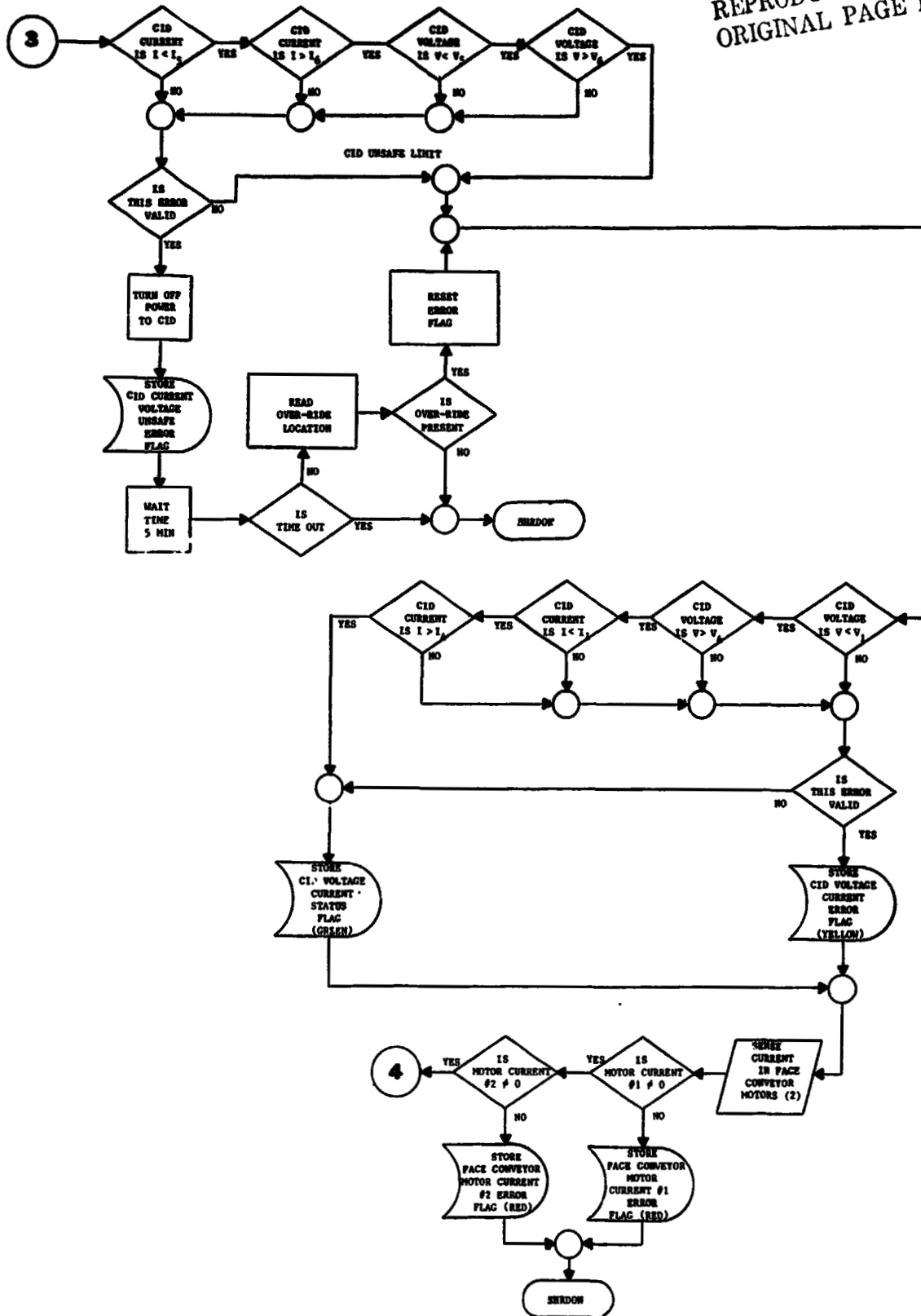


Figure 4-10. Status Monitor (STATDO)  
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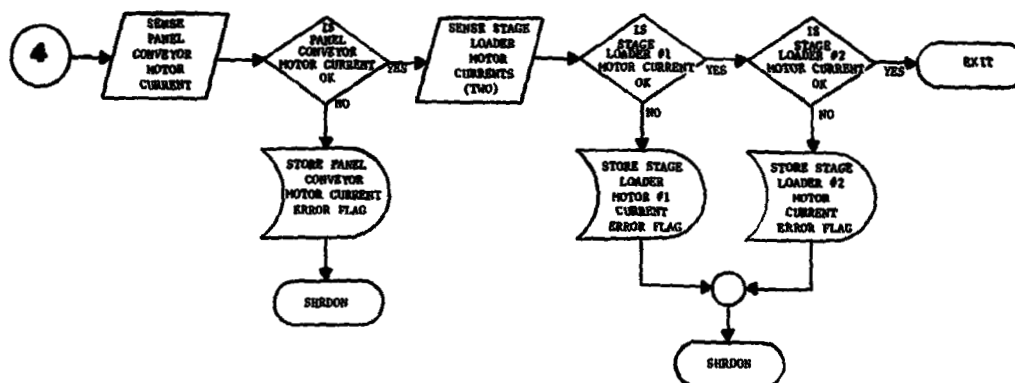
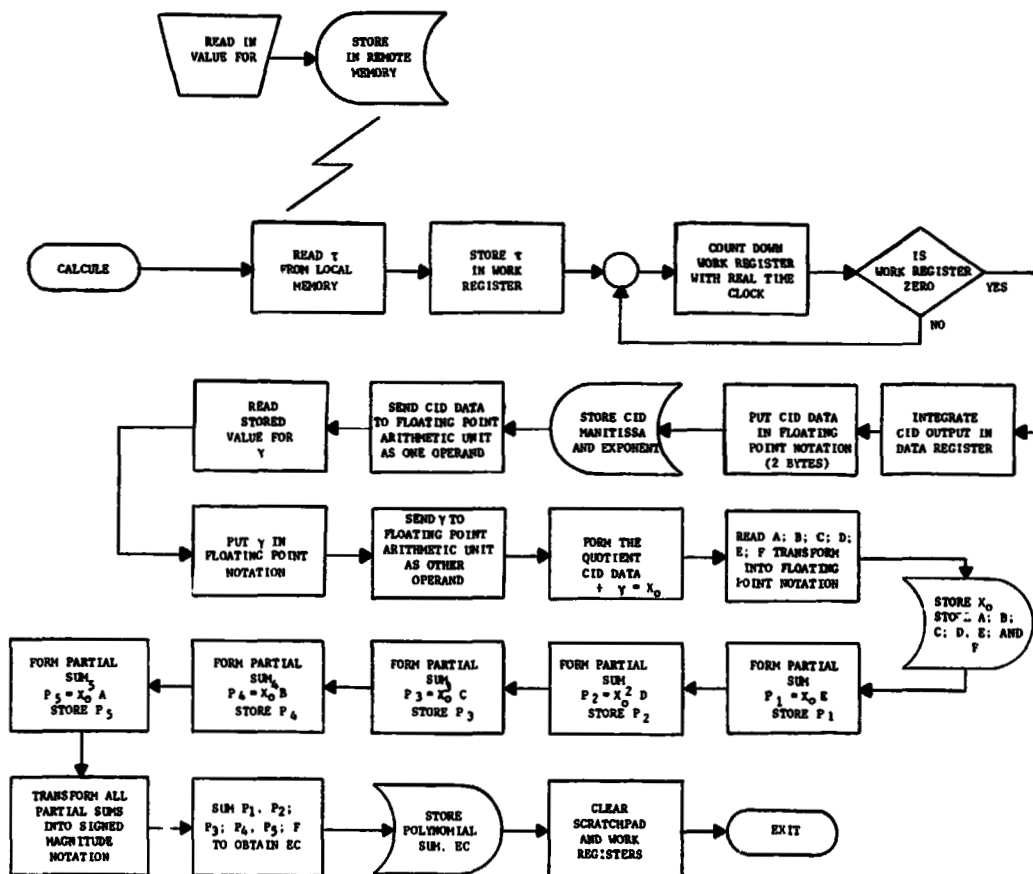


Figure 4-10. Status Monitor (STATDO)  
(Page 5 of 5)



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Figure 4-11. CID Calibration Correction (CALCULE)

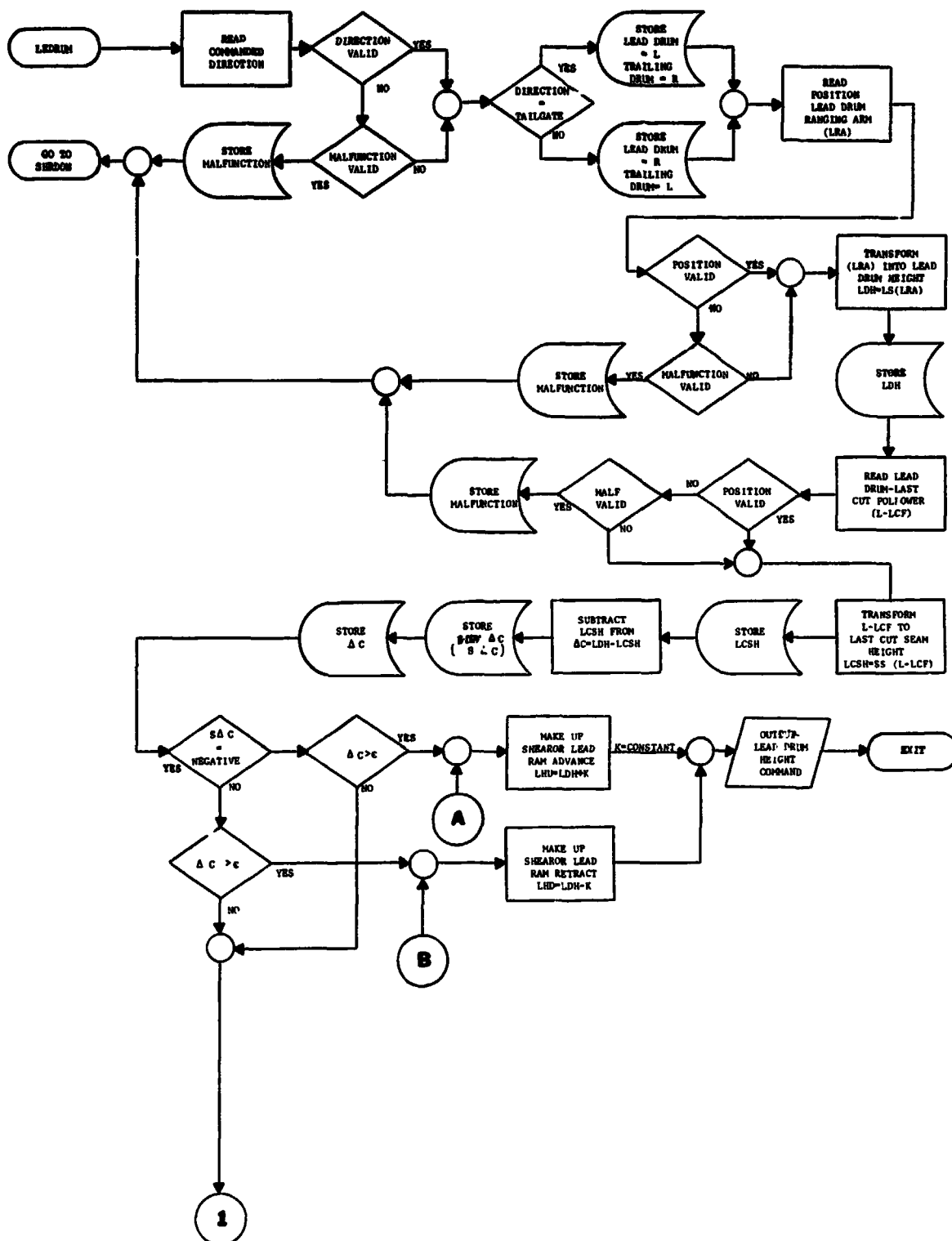


Figure 4-12. Lead Drum Control Algorithm (LEDRUM)  
(Page 1 of 3)



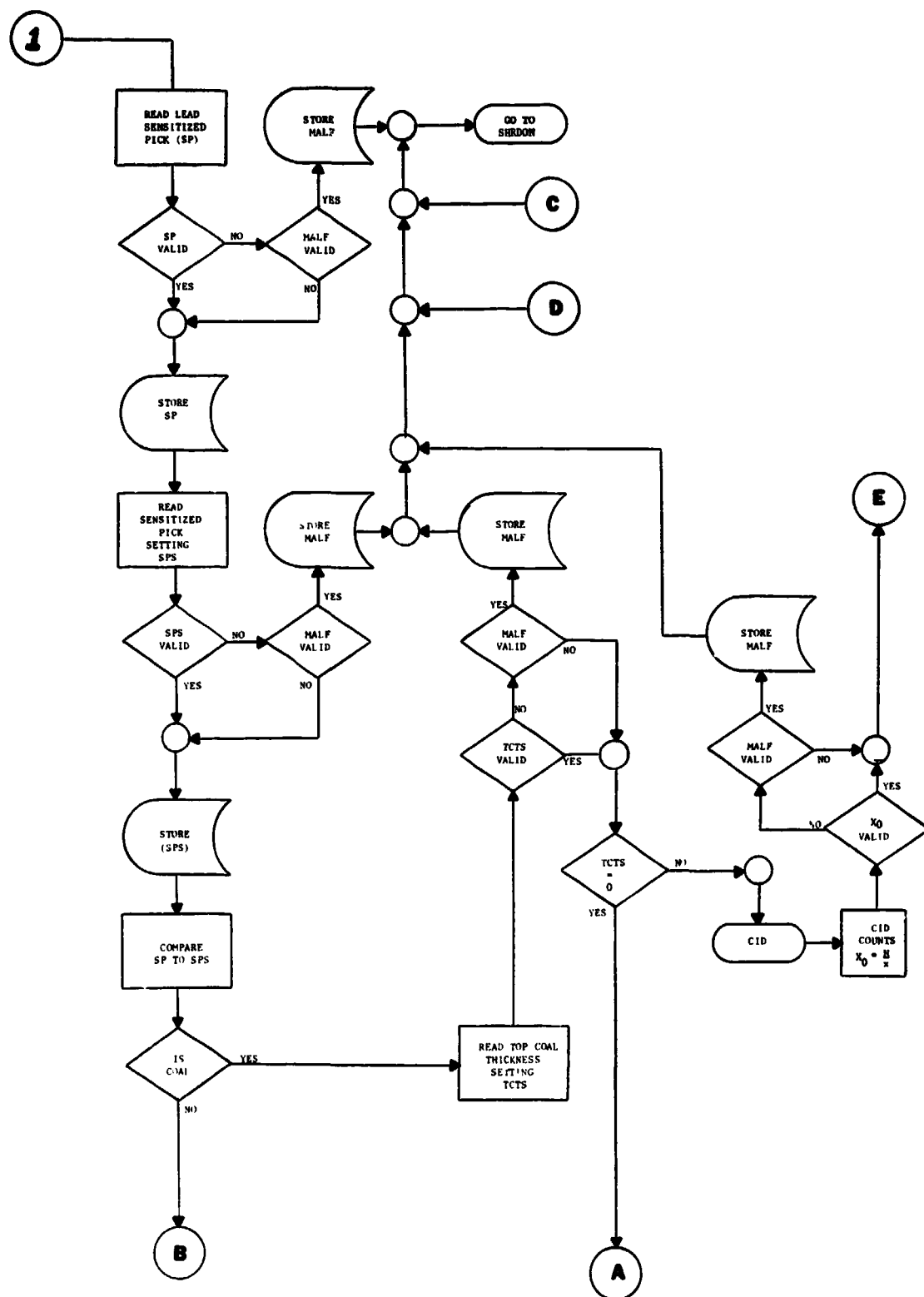


Figure 4-12. Lead Drum Control Algorithm (LEDRUM)  
(Page 2 of 3)



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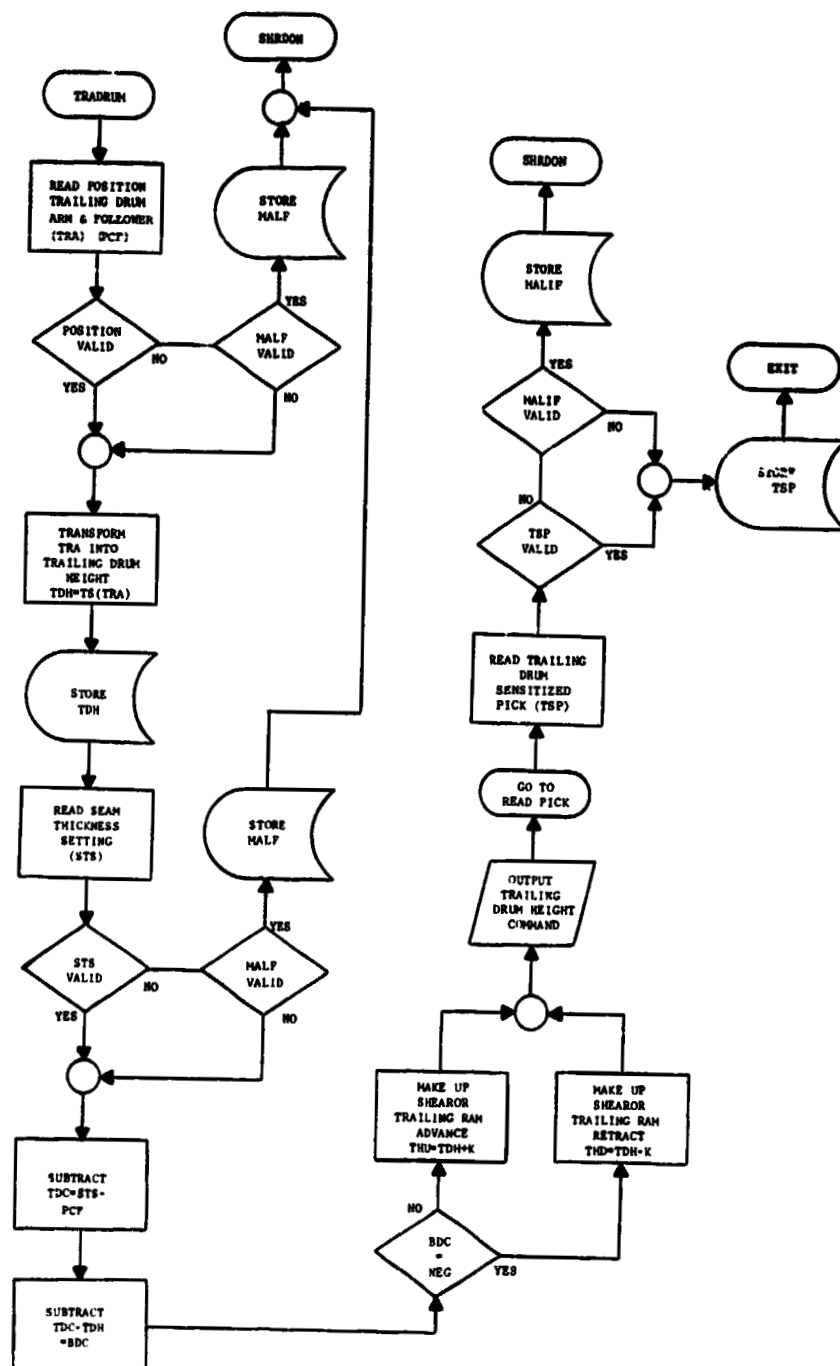


Figure 4-13. Trailing Drum Control Algorithm (TRADRUM)

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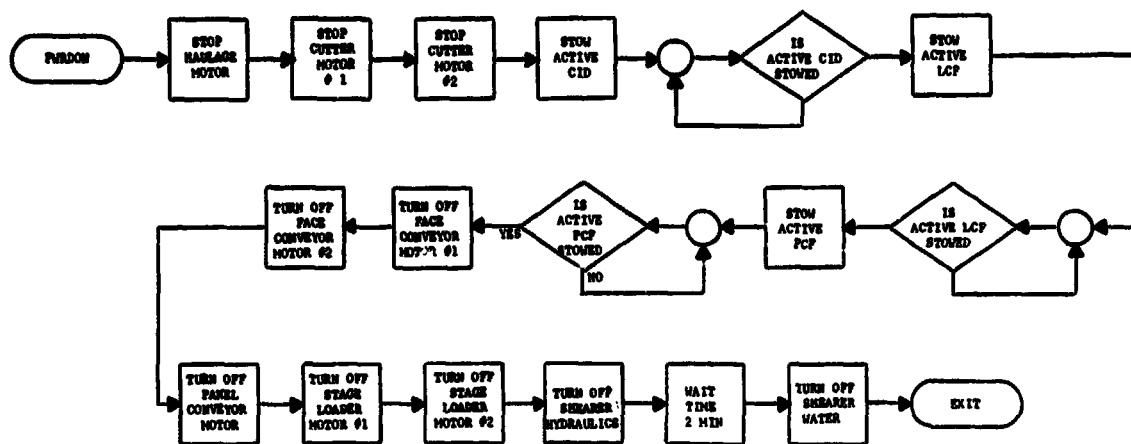
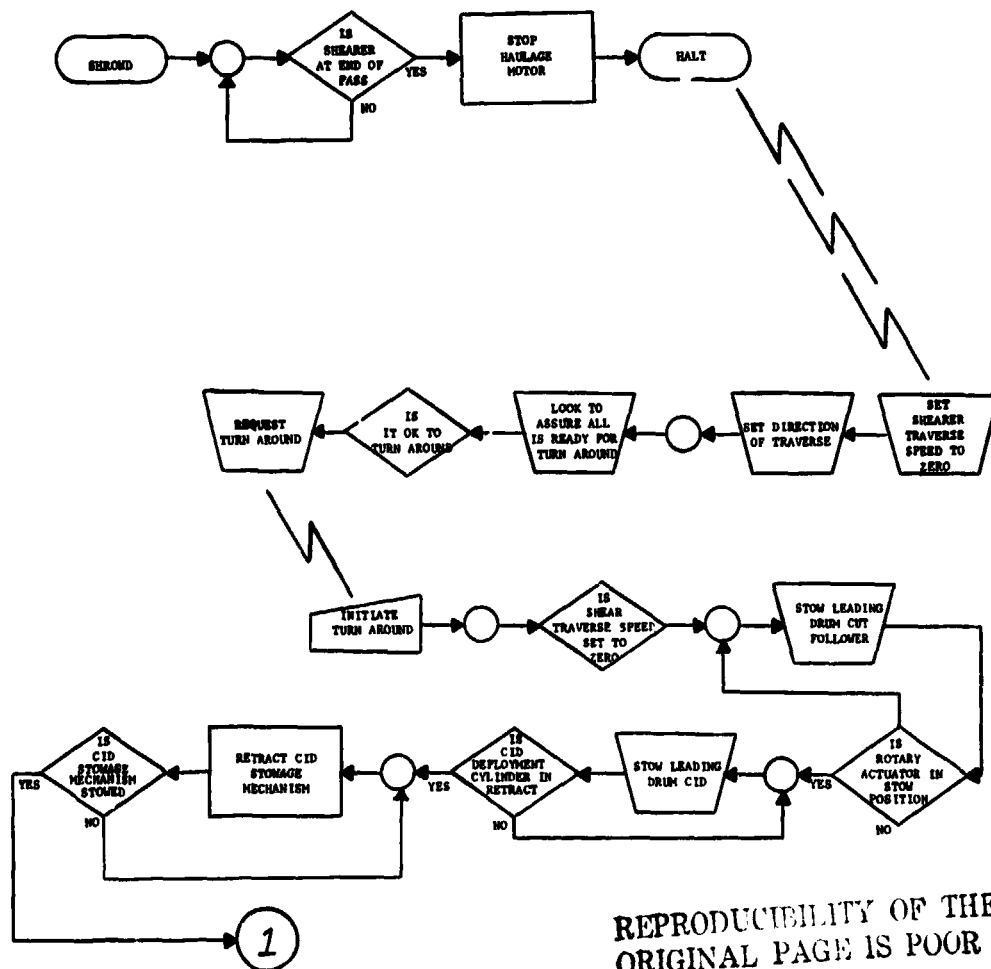
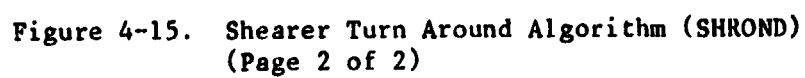


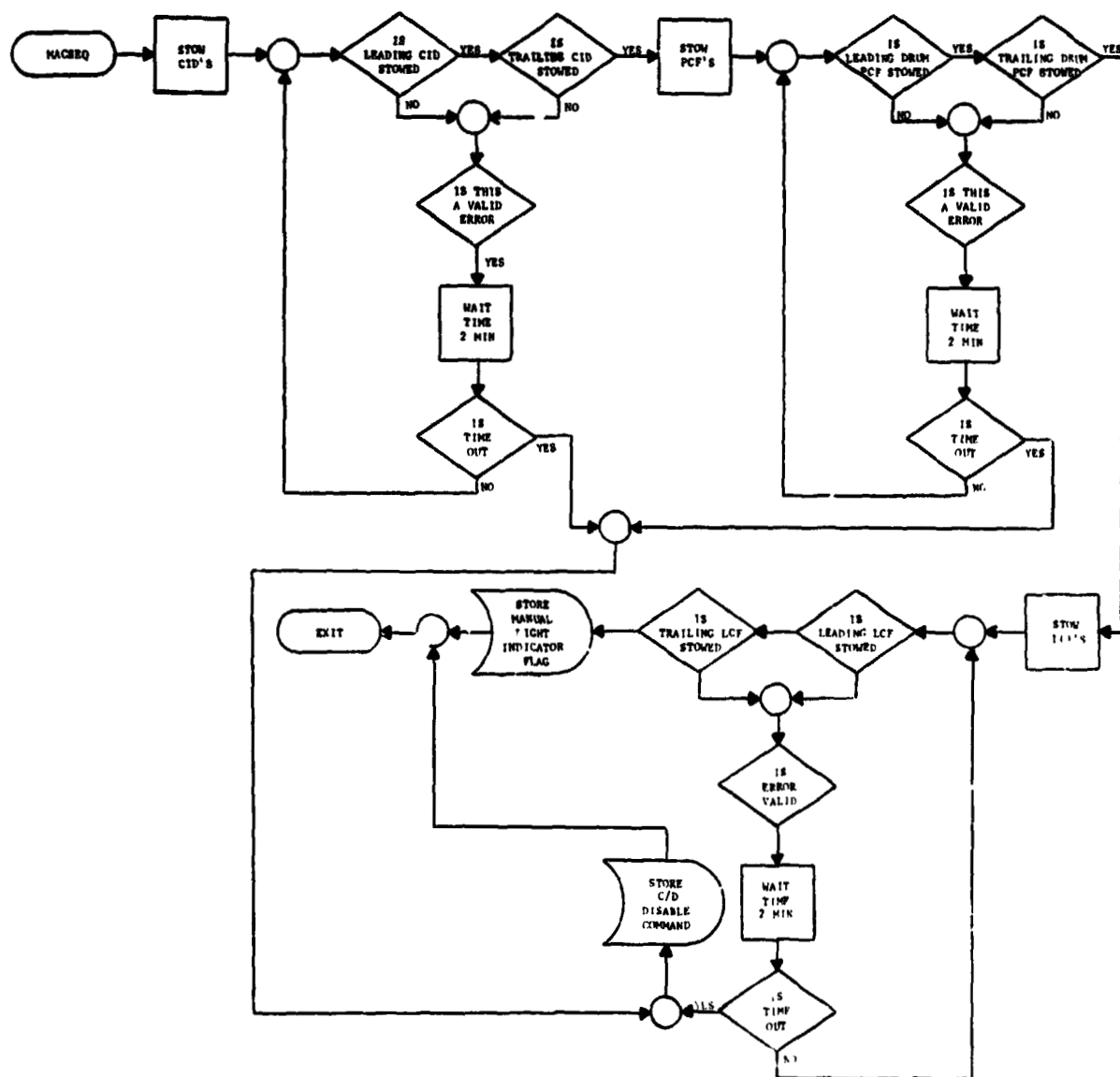
Figure 4-14. Normal Power Off Sequence (PWRDON)



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Figure 4-15. Shearer Turn Around Algorithm (SHROND)  
(Page 1 of 2)

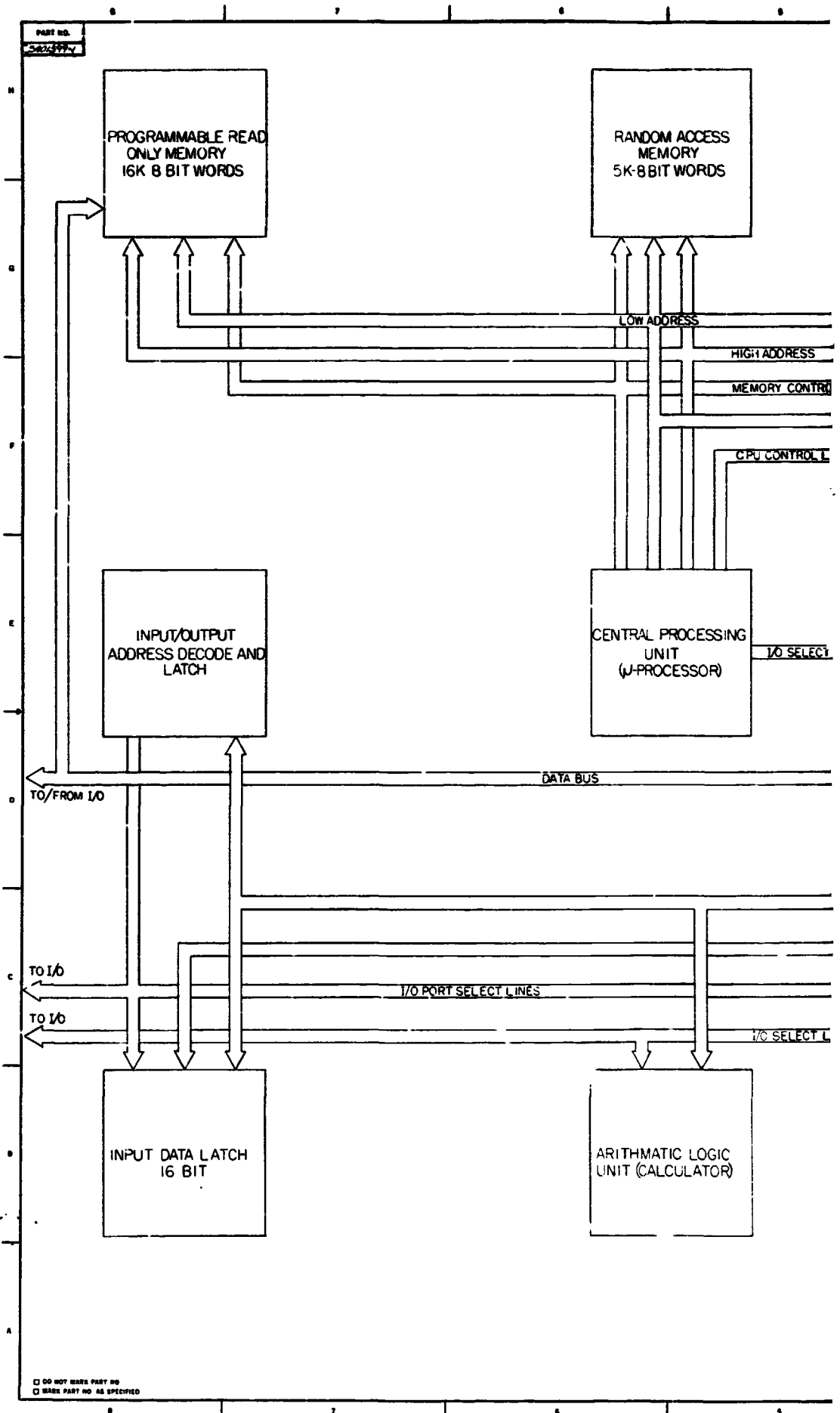




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Figure 4-16. Manual Mode Control Sequence (MACSEQ)

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The reasons for selecting the 1800 series microprocessor are the following: a) reliable second sources of supply exist, b) is structured more like the optimized computer structure of the PDP-11 rather than the earlier concepts found in the IBM-360, c) this series has a single phase clock which allows it to run at a rate from DC to above 5 MHz. The structure of the 1800 series is well suited for control applications such as the one presently being considered. The single phase clock makes troubleshooting relatively easy with less sophisticated test equipment for many of the problems encountered in equipment of this type.

4.2.2.1 CPU - The Central Processing Unit (CPU) is the microprocessor portion of the Main Processing and Control Computer. This device is employed as the intelligence of the ECM and follows a set of instructions stored in Programmable Read Only Memory (PROM). The input ports are read by addressing the one it desires and the data is then transferred to a self contained register or in to a specific RAM location for subsequent use. The data transferred may be operated upon in many ways, from logic operations, to shifting operations, to arithmetic operations for data manipulation, masking, evaluating or computing.

The CPU outputs control and display data based upon the previously described computations. The CPU also makes the decision when the communications subassembly may read or write to/from its RAM, and makes all the decisions for automatic operation of the longwall shearer.

4.2.2.2 The Memory Address Latch - The memory address latch is a latching device employed by the 8 bit machine to enable a 16 bit address or 64,000 8 bit words of memory. This device latches the first 8 bits of address which may then be employed with the second 8 bits to produce a 16 bit address. This address is employed to address the RAM and the many input/output ports it must service.

4.2.2.3 Random Access Memory (RAM) - The RAM employed within this subsystem is for temporary storage of computations and data. The CPU may read from and write to the RAM. Portions of this RAM are employed as scratch pads, for computation. Only a few of the RAM locations are employed as scratch pads. The bulk of the 5,000 8 bit words are required for storage of algorithms which will be used to enhance and optimize the operation of the shearer in the early stages of evaluation of the automated longwall system.

As with the other electronics within the ECM, the CMOS technology has been selected for the random access memory. The justification for this choice is that of low power, high reliability, and high noise immunity.

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**4.2.2.4 Programmable Read Only Memory (PROM) -** The PROM employed within this subsystem is for permanent storage of the operational firmware, and constants, required by the CPU in its sequencing and computations. PROM was selected over ROM (Read Only Memory) because the possibility of changes in the operational firmware of this first system. The PROMS selected are capable of being erased with ultra violet light and reprogrammed thereby modifying the operational firmware.

The flow diagrams were evaluated for relative complexity. An average routine was then selected and partially developed to determine its required firmware. The remaining algorithms were then estimated relative to the average algorithm to determine their respective firmware requirements. The firmware estimates were totaled to about 14,000 8 bit words. An additional 2,000 words were included for expansion resulting in a PROM size of 16,000 words. This number agreed with the initial top level estimate made at the beginning of the preliminary design.

At the time of this report there are no CMOS PROMS available so low power MOS devices were chosen which require a single power supply. These devices require relatively low power in the active state and may be powered down further when not being accessed, which result in low power operation.

**4.2.2.5 I/O Select Decoder -** The I/O select decoder is the decoding logic which decodes the microprocessor direct I/O select words into a single enable line, which represents the number described by that I/O select word. These lines are employed to select 8 input and output ports directly. These decode lines are employed to assist in the addressing of I/O ports, thereby extending the number of input/outputs which may be serviced.

As before, and for the same reasons, CMOS technology has been selected for this portion of the main processing and control computer.

**4.2.2.6 I/O Address Decode and Latch -** The I/O address decode and latch devices are latching decoders which will decode the memory address lines into discrete lines which represent the I/O device selected by the memory address lines. This technique is employed because of the numerous input ports which must be serviced.

CMOS technology has been chosen for use in these circuits for the same reasons previously described.

**4.2.2.7 The Arithmetic Logic Unit (ALU) (Calculator) -** The ALU portion of the CPU electronics is employed for the solution of some

of the equations used in the control algorithms. These equations involve multiplication and division of floating point numbers and would require too much of the CPU time for a solution.

The CPU loads the 16 bit input data latch with the numbers required for calculation. The CPU also provides the control lines required for the computation. The results of the computation is loaded into the 32 bit output data latch where it may be stored or acted upon by the CPU.

Low power technology is employed in the ALU unit. CMOS technology will be employed in the hardware providing a satisfactory device is available at the time of the hardware build.

**4.2.2.8 16 Bit Input Data Latch** - The 16 bit input data latch is employed, as previously mentioned, to receive and store data from the CPU for use by the ALU in its computations of 16 bit numbers. This device receives two eight bit words from the CPU and latches the data into a 16 bit word.

CMOS technology is employed for these devices for the same reasons previously described.

**4.2.2.9 32 Bit Output Data Latch** - The 32 bit output data latch is employed, as previously mentioned, to accept the answer from the 16 bit computations performed by the ALU unit. This data latch stores the 32 bit answers generated in the ALU until the CPU can read them into memory. Some consideration was given to disregarding the least significant 16 bits of the answer because of their insignificance in the control. The decision to keep all 32 bits was based on maintaining this capability for development evaluation, trend analysis, and system growth. The control for this latch comes from both the CPU and the ALU.

CMOS technology is employed for these devices for reasons previously mentioned.

**4.2.2.10 Hex Display and Driver** - The hex display is employed for trouble shooting. These devices are connected to the address and data bus lines to decode and display, in hexadecimal (0-F), the addresses and data on these lines. The Hex Display Driver is CMOS devices employed to decode the binary inputs and produce an output drive to the specific segments of the Alphanumeric Display which represent that character. These devices, along with the Hex Display are mounted on one of the logic cards within the ECM.

The display devices employed are low power liquid crystal devices. The drivers for the displays employ CMOS technology for the same reasons previously mentioned.

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4.2.2.11 Bus Isolator - The bus isolator is employed as an interface between the MPCC and the communications portion of the ECM electronics. The interface is required to connect the address and data bus lines between these two subsystems and allows the communications subsystem access to the MPCC memory. The communications subsystem reads memory for transmission to the MCS and Roof Support Electronics. The communications subsystem access to the MPCC memory also allows data to be transferred into this memory from the MCS and Roof Support Electronics.

The control for the bus isolator comes from MPCC control lines and are employed to start a hardware counter, open up the bus isolator and then halt to await a signal from the timer. The timer will restart the MPCC and close the bus isolator whereby both the MPCC and the communications processor will continue their independent routines, isolated from each other.

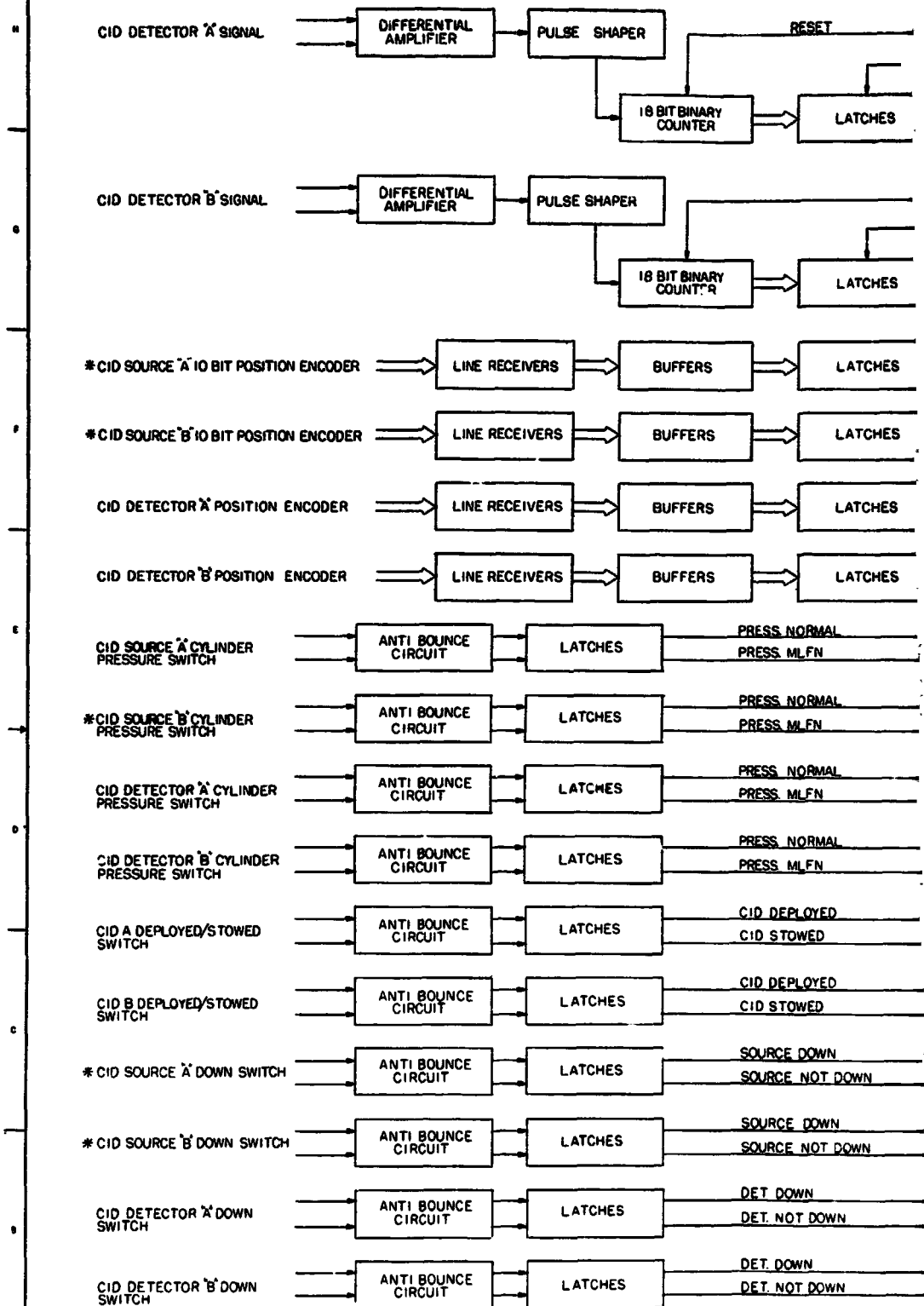
4.3 VCS Signal Conditioning - The VCS signal conditioning electronics, shown by the Signal Conditioning Block Diagram of Figure 4-20, serves to interface all the input signals to the input ports, for use by the Main Processing and Control Computer. The signal conditioning electronics also serves to interface all of the output signals from the output ports of the MPCC to the solenoids driving various controls and actuators.

The input signals come from sensors, switches, and digital encoders. The output signals consist of signals for driving either solid state relays or high voltage darlington drivers. The solid state relays and darlington drivers are located in the Power Supply box due to the "intrinsically unsafe" voltage levels which these devices switch. The solid state relays energize motor contactors and the high voltage darlington drivers energize hydraulic cylinders' pilot solenoids.

#### 4.3.1 Input Signals

4.3.1.1 Nucleonic CID Signal Conditioning - The shearer incorporates two (2) CID assemblies for cutting drum control of the double ended ranging arm shearer. Each assembly consists of a nucleonic source and a radiation detector. The detector output to the ECM is a low level pulse like signal train whose average frequency varies depending on roof coal thickness. A differential amplifier increases the low level signal while providing common-mode noise rejection. The amplifier signal is then processed by a pulse-shaping circuit yielding square pulses. The pulses, then, are counted by an 18 bit binary counter, allowing a maximum count of 2,500 pulses per second for up to 60 seconds. The 18 bit counter reset line, controlled by the MPCC, is adjustable between 0.1 and 60 seconds. This programmable counter is employed to compute "N" in both the CALCULE and LEDRUM flow charts previously described.

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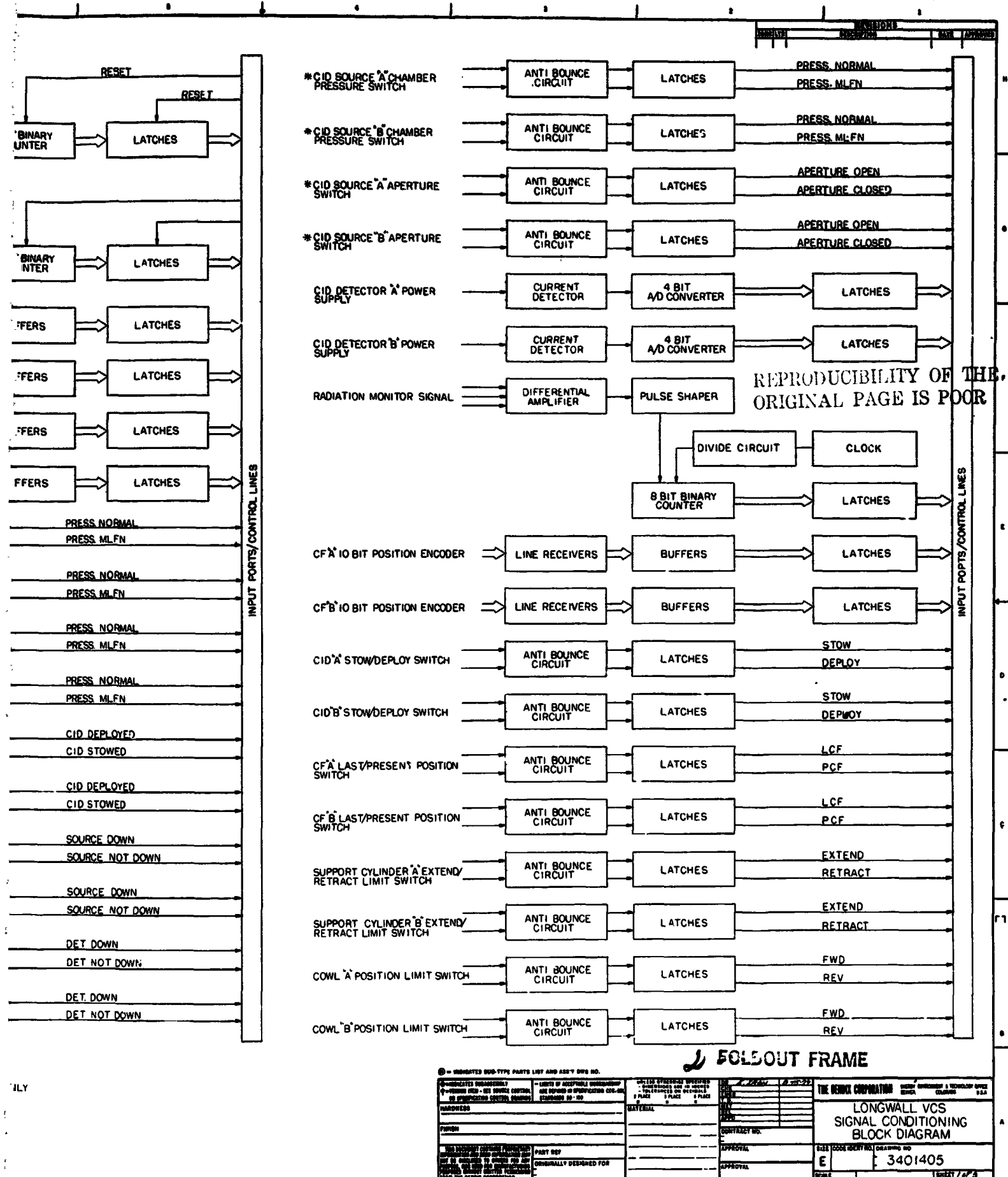


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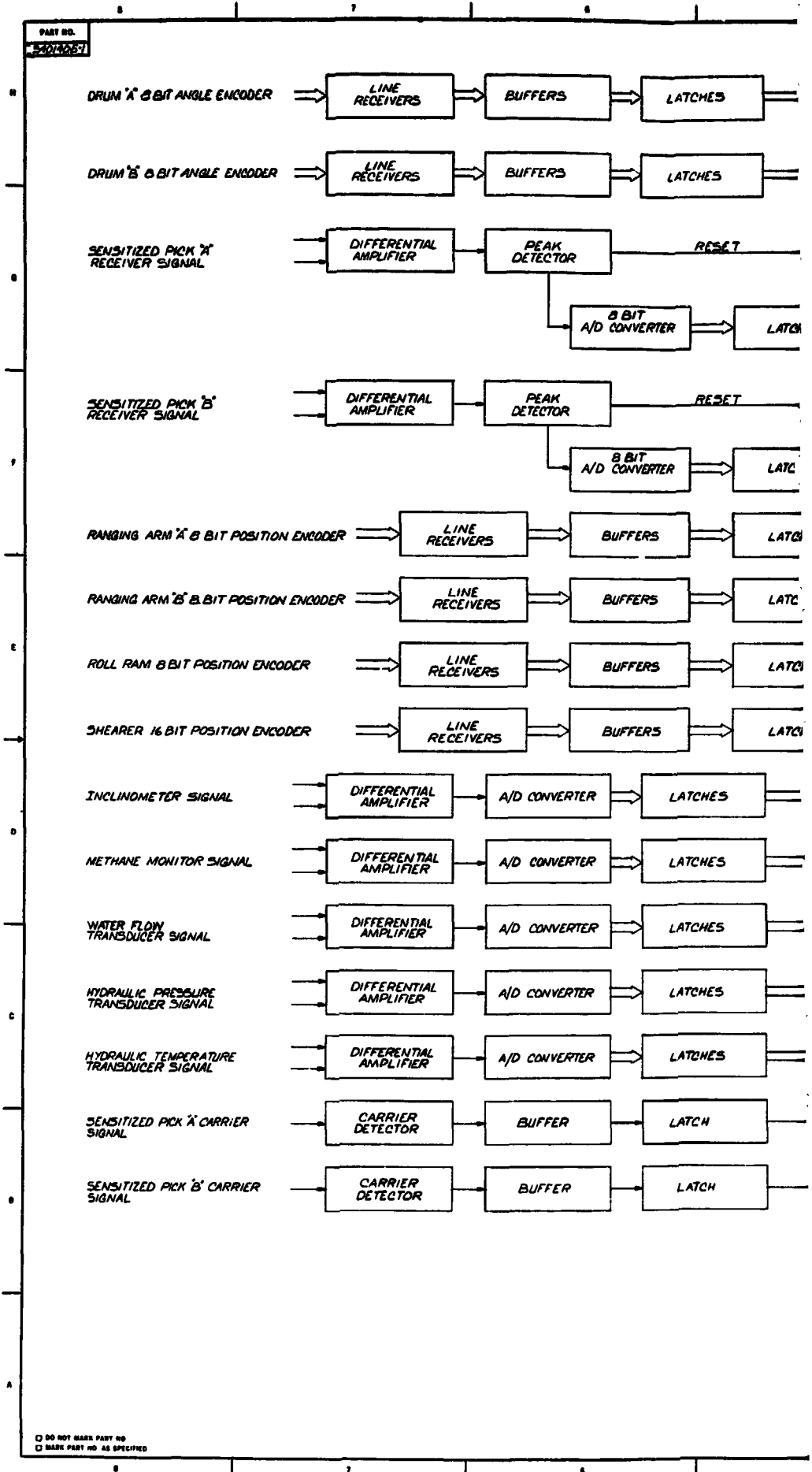
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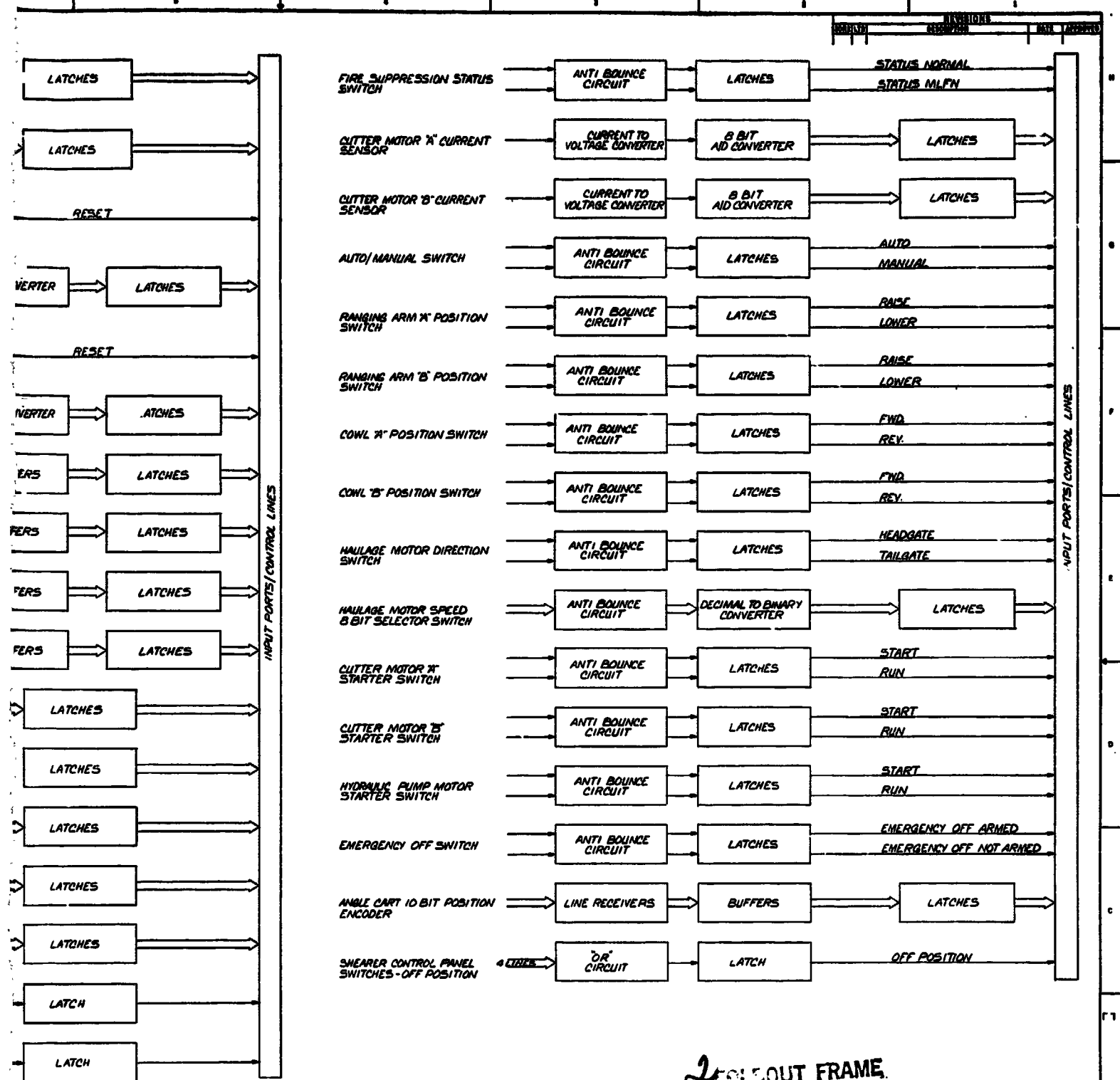
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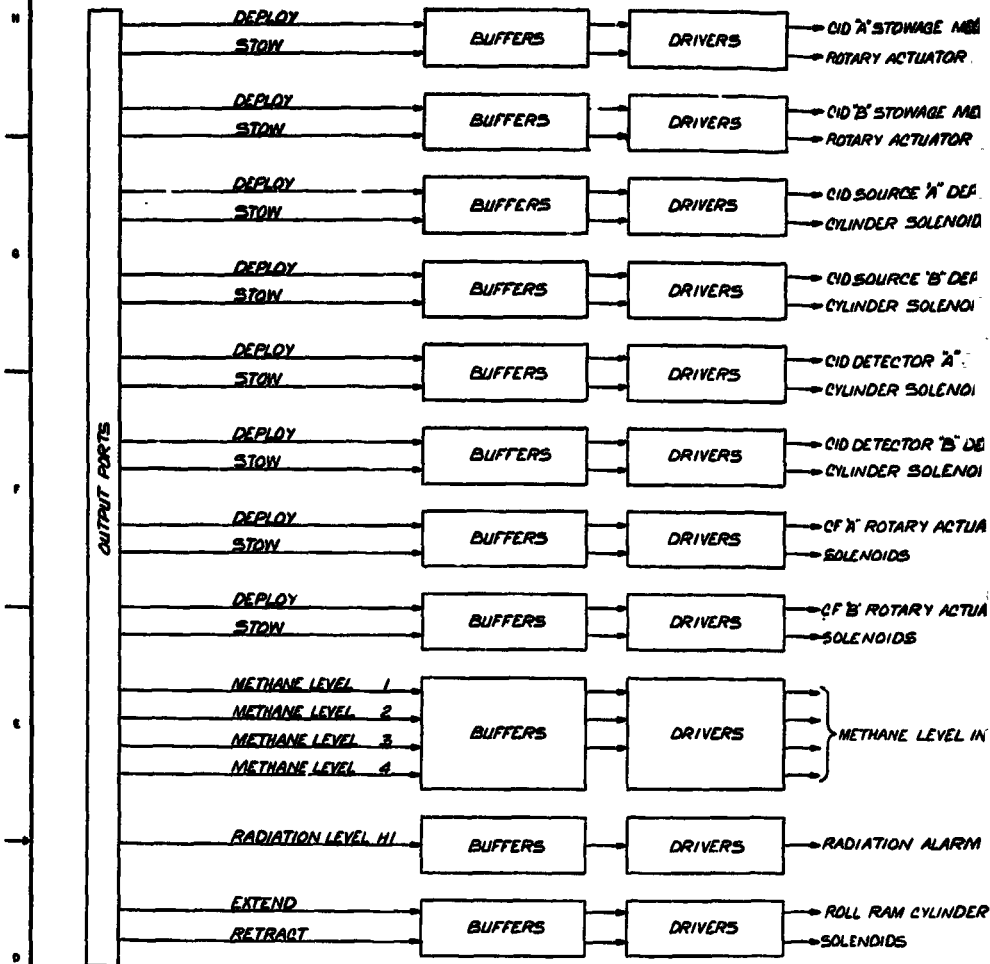
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Figure 4-20. (Page 2 of 3)  
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NOTES:

1. ASTERISK (\*) ITEMS ARE PECULIAR TO NUCLEAR CID
2. ALL LATCHES ARE RESETTABLE. RESET LINES (FROM CONTROL LINES) ARE NOT SHOWN

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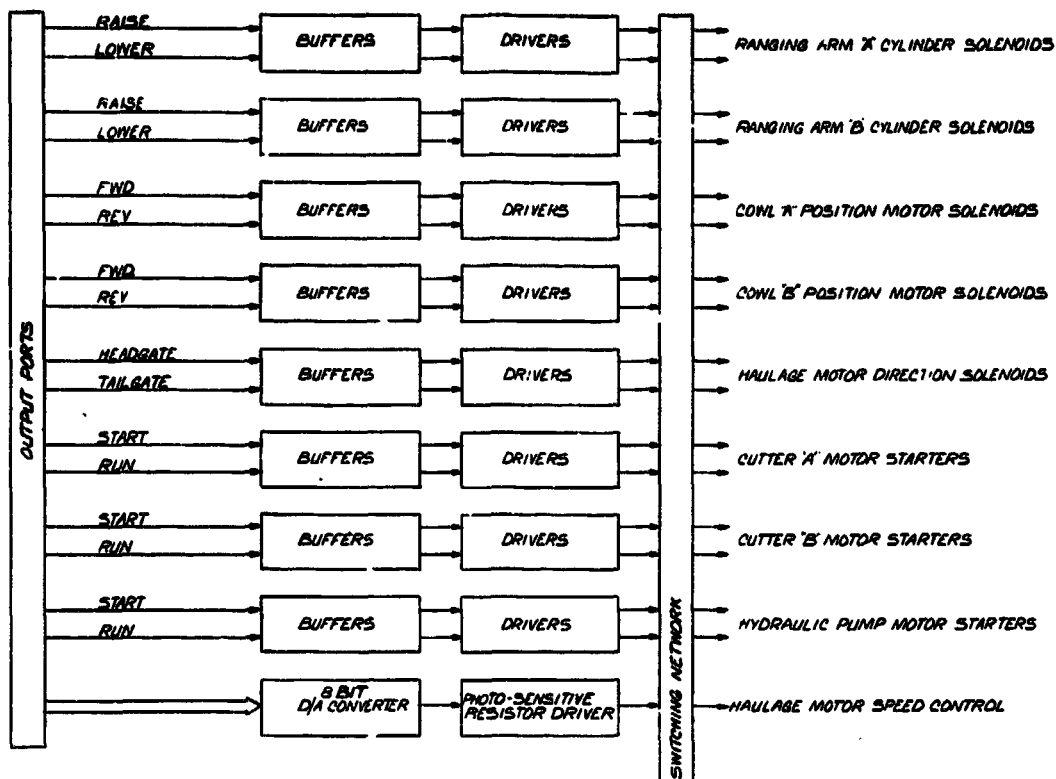
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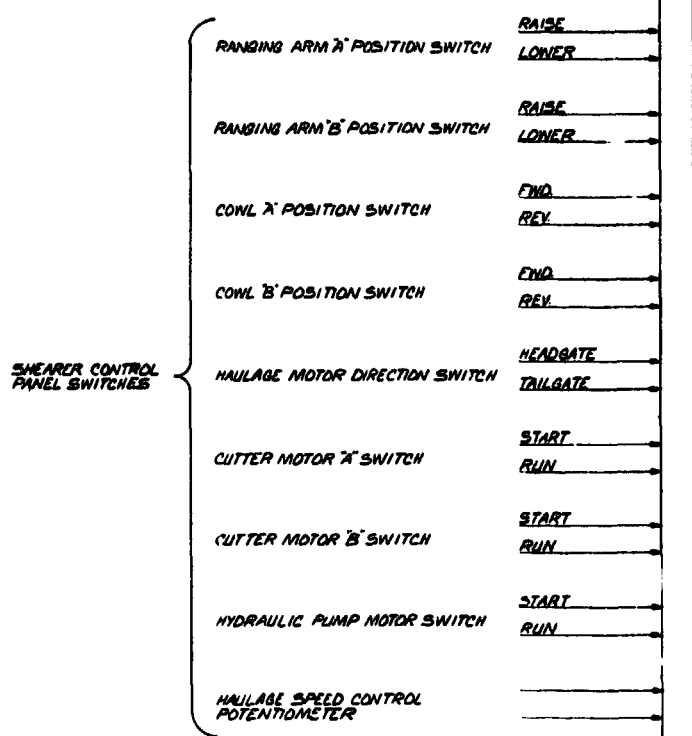
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THE DENCO CORPORATION LONGWALL VCS SIGNAL CONDITIONING BLOCK DIAGRAM		3401405		3401405	

Figure 4-20. (Page 3 of 3)

In order to process the CID signal intelligently, the relative position of the CID with respect to its mounting point on the shearer must be known. Since the CID source and detector mechanisms are independently floating, each has a 10 bit absolute-position encoder reading its position relative to the shearer mounting point, which will be averaged. The encoder output, through line drivers, is matched by line receivers in the ECM signal conditioning electronics. The 10 bit data is then buffered into data latches, which are resettable by the computer once data is clocked into the input ports.

In addition to the CID signal and encoder data, switches and sensors are required to determine various CID status: The hydraulic pressure of the preload cylinders monitored to determine that each of the CID sensors and detectors is engaged against the roof. The CID mechanism-source and detector has a stow/deploy switch to sense either position. Prior to stowage of the CID mechanism, both the CID source and detector must be lowered. Stowage position switches are available to sense CID mechanism stow position. All of the above switches are routed to the computer input ports through debounce circuits and data latches. The debounce circuits - RS type flip-flops - accept the first contact closure of the switches and ignore other multiple bounces, which the computer then treats as discrete pulses. The switch information is stored in data latches to be later used by the input ports. Once the input ports fetch the data then the computer may reset the data latches.

When using the Active Nucleonic CID, certain precautions must be taken to give proper warning since the nucleonic CID may present a radioactive hazard. Sensors have been placed at strategic locations to monitor various functions indicating safe or hazardous condition: The CID source chamber is pressurized, and a sensor switch monitors the pressure at all times. A drop in pressure indicates leaking gas and a possible rupture of the main structure thus resulting in a radiation hazard. A source aperture switch is used to monitor whether the aperture cover is open or closed depending whether the CID is deployed or stowed. Also, the CID detector power supply current is monitored to ensure proper operation of the CID electronics. The sensor switch signals are routed through debounce circuits and data latches to the input ports. It should be noted that all of the radiation hazard detectors are operable even when power to the shearer is turned off. This is accomplished by using a separate battery pack located in the power supply box. A loud audible alarm indicates a possible radiation hazard. Finally, there is a dedicated radiation detection device on the shearer that continually monitors the immediate environment on the shearer. The radiation detector output signal consists of low level pulses. The signal is processed by a differential amplifier, a pulse-shaper and gets counted by a 8 bit binary counter. The 8 bit outputs of the counter are stored in data latches

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to be used later by the input ports. The 8 bit counter is resettable by an external adjustable clock. The radiation detector will directly drive an audible alarm even if shearer power has been removed. The CID detector power supply current signal is routed through a current to voltage converter (an LED photo-transistor isolator) and then digitized by a 4 bit A/D coverter and then latched.

4.3.1.2 Cut-Followers Signal Conditioning - The shearer has two (2) cut-follower device one near each drum which can either follow the past or present cut, depending on whether the particular drum is leading or lagging. Each cut follower has a 10 bit angular absolute position encoder that follows the roof cuts. The digital data is routed through line receivers, buffers and latches to the input ports, as all other encoder data. Each cut follower has status switches associated with it: Stow/deploy position switch, LCF/PCF position switch, and support cylinder extend/retract switch. All these switches, like other switches, are routed to the input ports via anti-bounce circuits and data latches.

4.3.1.3 Sensitized Pick Signal Conditioning - The sensitized pick signal is transmitted from the rotating drums to a stationary point on the shearer via FM telemetry system. The FM receiver output in a low level signal which is routed to a differential amplifier. The signal is then peak detected and converted to digital data via an 8 bit A/D coverter. The data is then made available to the input ports by way of data latches. The status of the sensitized pick is checked by monitoring the presence of the FM carrier signal. The carrier is detected, buffered and then sent to the input ports for use by the MPCC.

4.3.1.4 Inclinator Signal Conditioning - The inclinometer is a device used to measure tilt angle of the shearer with respect to the vertical. The inclinometer output is an analog signal whose level is proportional to the tilt angle. A differential amplifier is used to bring the signal to a proper level for digital processing by a 8 bit A/D converter and also to reject common-mode noise. The 8 bit digital data is then latched for the input port transfer to the MPCC.

4.3.1.5 Additional Sensors Signal Conditioning - The following signals undergo conditioning by identical ECM signal conditioning circuits: Methane monitor, water flow sensor, hydraulic pressure sensor, hydraulic temperature sensor, and cutter motor current sensor signals are all analog, low level. Each signal is conditioned by a differential amplifier whose output is converted to digital data by an A/D converter. The digital data is then routed to data latches. The input-ports will fetch the data from the data latches and the MPCC control line will reset the data latches so that fresh data can be stored. The cutter motor current sensor outputs a voltage proportional to current, which is then amplified by a differential amplifier.

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**4.3.1.6 Additional Limit Switches Signal Conditioning** - Throughout the VCS (Vertical Control System) there are a number of limit switches used for status monitoring which were not discussed previously: Support cylinder extend/retract limit switch, cowls forward/reverse position limit switches and fire suppression status switch. The above switch signals are routed to the input ports through debounce circuits and data latches. As in previous cases, the data latches are reset by the MPCC control lines once data is used by the input ports.

**4.3.1.7 ECM Control Panel Switches** - Certain shearer mechanisms can be exercised by using the control panel switches and are only used during checkout of ECM. The following functions can be manually controlled: Ranging arm raise/lower - one for each arm, cowl forward/reverse - one for each cowl, haulage motor direction, haulage motor speed cutter motor start/run - one for each motor, hydraulic pump motor start/run. In addition to these control switches the control panel has an auto/manual switch and an emergency off switch.

All of the above switch setting signals with exception of the haulage motor speed, are routed to the input ports by way of anti-bounce circuits and data latches. The haulage motor speed selector switch provides 8 switch positions to a decimal to binary converter through an anti-bounce circuit. The output of the decimal to binary converter consisting of 3 bits of data is stored in data latches, to be used later by the input ports.

**4.3.1.8 Shearer Control Panel Signal Processing** - All the OFF positions of the manual controls on the shearer mounted control panel are routed to a NOR circuit. If any of the switches is not in the OFF position then a signal results at the output of the NOR circuit, and it is latched. The automatic sequence cannot resume if the computer recognizes such a signal.

**4.3.1.9 Additional Absolute Position Encoder Signals** - In addition to the encoders already mentioned previously there are a number of others at various locations on the shearer. The purpose of the encoders are to translate a position, whether linear or angular, into MPCC data words. The following list summarizes the remaining encoders, which provide 8 bits of output data except as noted. Drum angle - one for each drum, ranging arm actuator extension - one for each arm, roll ram extension, angular rotation of haulage pinion gear for shearer position along face - two (2) encoders, angle cart - 10 bit encoder.

All of the encoder data is outputted through line drivers, built into the encoders. Therefore, at the ECM signal conditioning electronics, the digital data from the encoders is terminated in matching line receivers. The data then is buffered to data latches. The input ports fetch the data from the data latches and the MPCC control lines reset the data latches, at the proper time.

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**4.3.2 Output Signals** - The ECM signal conditioning electronics process two types of signals: those that actuate electromechanical devices and those that activate status indicators and alarms.

**4.3.2.1 Signals Actuating Electromechanical Devices** - Most of the data from the output ports to the signal conditioning electronics is used to drive electromechanical devices. Each signal is routed from the output ports through buffers and drivers. The drivers are 115 VAC solid state relays, where motor contactors must be energized - cowls, haulage, cutter, and hydraulic pump motors. Darlington transistor drivers are used to actuate 110 VDC solenoid piloted hydraulic valves for the CID stowage mechanisms, CID deploy cylinders, cut follow rotary actuators, roll ram and ranging arm cylinders. The solid state relays and darlington drivers are located inside the Power Supply box.

**4.3.2.2. Status Indicators and Alarm Signals** - Four data bits from the output ports are used for methane level indication. The data bits are buffered and used to drive darlington transistor drivers. The darlington, in turn, drive LED lamps that indicate various methane levels.

A radiation audible alarm on the shearer gets activated by another data bit from the output ports. A buffer and darlington driver circuit is used to interface this data from the output port to the alarm device. The radiation alarm device is powered by the battery pack in the Power Supply box and hence will continue to function even when shearer power is shutdown.

**4.3.2.3 Haulage Motor Speed Control Signal** - The haulage motor speed is controlled by 8 data bits from the output ports that are converted to an analog signal through a D/A converter. The analog signal then drives a photo-sensitive resistor, that behaves like the haulage motor speed control potentiometer on the shearer control panel.

**4.3.2.4 Control Signal Switching Network** - In the manual mode, various shearer command functions can be controlled by the shearer control panel, rather than by the ECM control panel, through a multi-contact switching network. The switching network is activated by the auto/manual mode switch on the shearer control panel. In case of ECM breakdown or loss of ECM power supply, the switching network reverts the shearer back to manual operation. The switching network is not affected by loss of power supply.

The controls that are switched by the switching network are: Ranging arms raise/lower, cowls forward/reverse, haulage motor headgate/tailgate, cutter motors start/run, hydraulic pump motor start/run, and haulage speed potentiometer.

**4.4 Design of Communications Subsystem** - The longwall automatic control system has interdependent subsystems separated by distances of 1200 feet or more. This interdependency requires communications be provided for voice and data between these integrated subsystems. A radio link would be preferred, from a mobility standpoint, but because of expense and communications reliability problems associated with the severe environment at the coal face, a cable link was selected for communications.

Information and control can be transmitted on a single line by using serial digital data between subsystems. A coax transmission line will be used to allow high data rates and to provide shielding from the high radio frequency interference environment caused by large electric motors in the area.

As a supplemental to the normal longwall voice communication system already present in the mine, a voice channel will also be maintained via the ECM electronics. This is done as a convenience for shearer maintenance, checkout, calibration and turn around. Voice communications may be carried on the same coax line that is used for digital data by using a separate carrier frequency. The digital data will be represented on the coax line as two discrete frequencies. A frequency shift keyed modulation is used to cause one frequency to be transmitted for a high (or one) bit, and a different frequency to be transmitted for a low (or zero) bit. Frequency shift keying (FSK) is employed to increase noise immunity on the long coax communications line. Control digital data is sent directly to an FSK modulator, and analog voice data is converted to digital form before it is also sent through an FSK modulator and then combined with the control data to be amplified and sent out on a communications line.

**4.4.1 ECM Communications Block Diagram** - Figure 4-21 shows a block diagram of the major components that compose the shearer communications system. Digital data is manipulated by a microprocessor unit that is dedicated to communications only. Associated with the Communications Processor Unit are Random Access Memory (RAM), Programmed Read Only Memory (PROM), and a memory address latch that is required to expand the addressing capability of the 8 bit bus to 16 bits (increases capacity to 65,536 locations).

Other portions of the longwall communications system will have the same type of communications interface. To receive data from the other units requires accurate synchronization of all transmit/receive operations. A master clock will be located at the MCS to supply a clock signal to the coax transmission line. An active filter tuned to the clock frequency will receive the clock signal and amplify it for use as an internal clock for all communications control functions.

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**4.4.2 Communications Inputs** - The ECM contains the control algorithms to operate the longwall shearer automatically. The automation requires data input from the MCS and the roof support electronic systems to perform its functions properly. Master controls such as initialize, auto start, set seam height, select top coal thickness, calibrate sensors and set shearer traverse speed are obtained from the MCS control panel. Status of the roof support system is also required by the shearer so that conveyor and roof support advance can be controlled properly in relation to the shearer movement in the automatic sequence. Data received from the control and display panel and the roof supports are listed in Tables 4-6 and 4-7.

The discrete command and status information is represented by 8 bit words or combined to form 8 bit words. Table 4-6 lists the command and status words from the MCS to the ECM where the 8 bit words are sent complete and 4 of the 2 bit words are combined to form 8 bit words for transmission. Each of these message sequences are preceded by two 8 bit words. The first word is a message start signal composed of all one bits; the second word is an identification word whose first 4 bits indicate the desired destination of the message, and the last 4 bits indicate where the message originated. There are then 8 words of message plus 2 words of message start coding for a total message length of 10 words or 80 bits.

The roof support to shearer message information list is given in Table 4-7. After combining messages where possible, there are 6 words of data required for each roof support. It is now planned to send 6 chock data sets per communication cycle, so that 36 words will be sent in sequence. Adding the two words of start code for this message results in a total message length of 38 words or 304 bits.

The messages described above are received in serial form from the communications transmission line. An active filter will receive the data bits. This data is converted in the frequency shift keyed demodulator to an NRZ data representation, which is then shifted into the Universal Asynchronous Receiver Transmitter (UART). When 8 bits have been received, a word is transferred in parallel to the communications processor data bus where the data is stripped out and then stored in appropriate memory locations. Input and output operations at the UART are controlled by the communications processor.

**4.4.3 Communications Outputs** - The ECM output consists of status information sent to the MCS and commands to the Roof Support Electronics System. The message format is the same for all messages in the communications loop. There is one start word and one identification word, followed by as many 8 bit words as needed to complete the message. A list of the information sent from the ECM to the MCS is presented in Table 4-8.

Table 4-6. MCS to ECM Messages

<u>Message Description</u>	<u>Number of Bits</u>
Control Power On/Off	2
Manual, Automatic, or Automatic Remote Manual Control	2
Drum Cutter Motor A Control	2
Drum Cutter Motor B Control	2
Haulage Motor Direction	2
Haulage Motor Speed	8
Ranging Arm A Extend/Retract Command	2
Ranging Arm B Extend/Retract Command	2
Pump Motor On/Off	2
A Cut Follower Deploy Command	2
B Cut Follower Deploy Command	2
CID A Deploy/Stow Command	2
CID B Deploy/Stow Command	2
Cowl A Control	2
Cowl B Control	2
Roll RAM Extend/Retract Command	2
Sensitized Pick Setting	8
Coal Thickness Setting	8
Request Data Address (DAS)	8

**Table 4-7. Roof Supports to Shearer Messages**

<u>Message Description</u>	<u>Number of Bits</u>
Roof Support Address (1 to 150)	8
Control Power On/Off	2
Manual or Automatic Control	2
Vertical Ram Status	2
Horizontal Ram Status	2
Roof Support Load (Pressure)	8
Vertical Ram Position	8
Horizontal Ram Position	8
Hydraulic Pressure On/Off	2

Table 4-8. ECM to MCS Message

<u>Message Description</u>	<u>Number of Bits</u>
Manual, Automatic, or Remote Manual	2
Control Power On/Off	2
Pump-Shearer On/Off	2
Hydraulic Pressure	2
Cowl A Position	2
Cowl B Position	2
Haulage Motor Direction	2
Hydraulic Filter Pressure Drop Limit	2
Methane Level	8
Water Flow	8
Drum B Current	8
Drum A Current	8
Haulage Motor Current	8
Cut Follower A Position	8
Cut Follower B Position	8
Coal Interface Detector Position	8
Coal Thickness Setting	8
CID Output (Coal Thickness)	8
Ranging Arm A Position	8
Ranging Arm B Position	8
Inclinometer Output	10
Cut Follower A Deployed	2
Cut Follower B Deployed	2
Sensitized Pick Level	8
Oil Level Sensor	8
Radiation Level Sensor	8
CID A Status	4
CID B Status	4
Data Addressed from DAS	8
Addressed Data Output	8

After combining data where convenient, there are 22 8 bit words or bytes of information, plus the two leading bytes for a total of 24 bytes.

A list of the commands sent from the ECM to the Roof Supports Electronics is presented in Table 4-9. The total number of bytes for one message is 20, composed of two leading bytes, and 6 sets of 3 bytes that are sent to 6 different Roof Support Electronic units. This is done by making the first byte of a set of 3 bytes be the address of the particular roof support for which the commands are intended. To completely command all 150 roof supports requires 25 communications cycles, since only 6 are addressed per cycle. Since one cycle now requires 25 milliseconds, all roof supports are commanded once per  $.025 \text{ sec.} \times 25 = 0.625 \text{ sec.}$  This seemed adequate for this VCS preliminary design but may be altered when the YAW alignment system is completed.

4.4.4 Other Communications - In order to size the communications time cycle, the other two links that do not involve the ECM are also included here. The MCS may command the roof supports electronics directly, and the roof supports electronics send status information directly to the MCS.

Table 4-10 presents the roof supports to control and display message, and Table 4-11 presents the control and display to roof support message. Combining data into packed bytes and adding the leading words for each message sequence results in a total of 8 bytes for each of the messages between roof supports and the control and display panel.

4.4.5 Communications Timing - To integrate the various communications subsystems, a communications cycle was defined which provides for the proper timing of transmitting and receiving information for each unit on the communications line. There are three basic subsystems in the overall system: the ECM, the MCS, and Roof Support Electronics (RSE). Each of the three subsystems sends one message to each of the other two subsystems once per communications cycle. To obtain the time required per cycle, the total message length and bit rate must be defined.

The limiting factor in determining bit rate results from the frequency shift keyed (FSK) modulator. The upper frequency recommended for the selected unit is 500 KHz. The bit rate should be about a factor of 10 lower to provide at least 10 cycles of the carrier in one bit time. The bit rate selected is 40 K bits/sec. The clock frequency of a UART must be set at 16 times the bit rate, or 640 KHz. The master clock on the C&D panel which coordinates the communications is therefore set to 640 KHz. With a bit rate of 40 K bits/sec, the 8 bit word (or byte) rate is 5000/sec.

**Table 4-9. ECM to Roof Support Electronics Message**

<u>Message Description</u>	<u>Number of Bits</u>
K + h Roof Support Address (1 through 256)	8
Conveyor Advance Amount	8
Advance Conveyor Command	2
Advance Roof Support Command	2
K + 1 Roof Support Address (1 through 256)	8
Conveyor Advance Amount	8
Advance Conveyor Command	2
Advance Roof Support Command	2
K + 2 Roof Support Address (1 through 256)	8
Conveyor Advance Amount	8
Advance Conveyor Command	2
Advance Roof Support Command	2
K + 3 Roof Support Address (1 through 256)	8
Conveyor Advance Amount	8
Advance Conveyor Command	2
Advance Roof Support Command	2
K + 4 Roof Support Address (1 through 256)	8
Conveyor Advance Amount	8
Advance Conveyor Command	2
Advance Roof Support Command	2
K + 5 Roof Support Address (1 through 256)	8
Conveyor Advance Amount	8
Advance Conveyor Command	2
Advance Roof Support Command	2

**Table 4-10. Roof Supports to Control and Display Panel Message**

<u>Message Description</u>	<u>Number of Bits</u>
Roof Support Address (Per DAS Request)	8
Control Power On/Off	2
Manual, Automatic, or Remote Manual	2
Vertical Ram Drive	2
Horizontal Ram Drive	2
Roof Support Load	8
Vertical Ram Position	8
Horizontal Ram Position	8
Hydraulic Pressure	2

**Table 4-11. Control and Display Panel to Roof Supports Message**

<u>Message Description</u>	<u>Number of Bits</u>
Roof Support Address	8
Manual, Automatic or Remote Manual	2
Vertical Ram Extend/Retract Command	2
Horizontal Ram Extend/Retract Command	2
Conveyor Advance Amount	8
Advance Conveyor Command	2
Advance Roof Support Command	2
Data Request Roof Support Address (DAS)	8
Sensor Address (DAS)	8



To define the total communications cycle, each of the six messages between subsystems was defined to determine message lengths as shown in Table 4-12 below.

Table 4-12. Communications Message Lengths

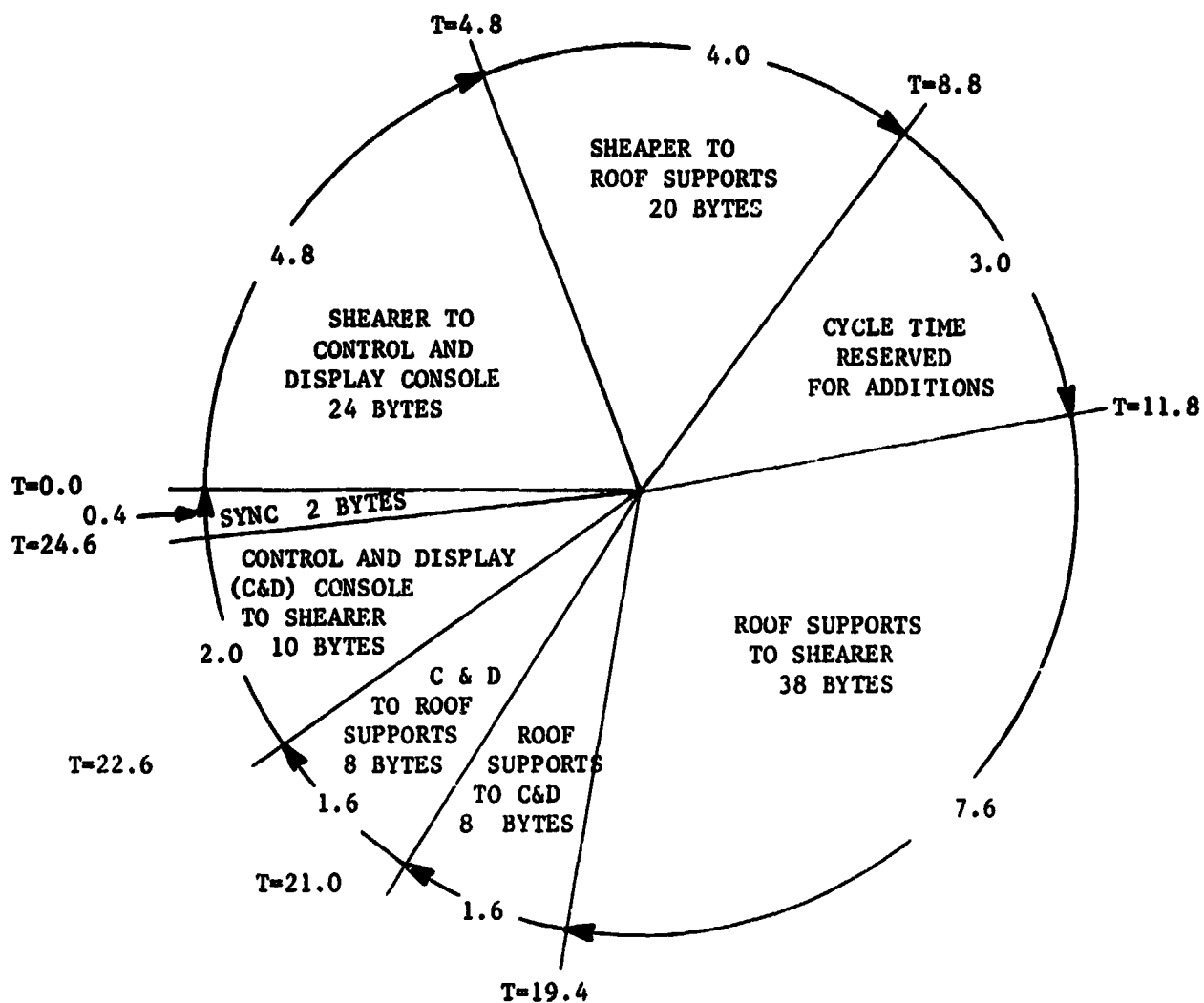
Message Description	Number of Bytes
Shearer to Control and Display	24
Shearer to Roof Supports	20
Roof Supports to Shearer	38
Roof Supports to Control and Display	8
Control and Display to Roof Supports	8
Control and Display to Shearer	10
Control and Display Sync Words	2
Total	110

Transmitting a total of 110 bytes at 5000 bytes/sec means that the minimum time for one cycle is  $110/5000 = 0.0220$  sec, or 22.0 milliseconds. To allow for some expansion in the event that some additional data needs to be transmitted, a cycle time of 25 msec was selected. Figure 4-22 shows the present definition of one complete cycle, including 3.0 milliseconds of off-time that is reserved for expansion.

The communications cycle is initialized by the MCS transmitter, which sends out 2 sync words on the transmission line and resets an internal counter. Each communications system on the line will use the sync words to reset their own internal counter to establish when their own transmission is to occur in the communications cycle. The MCS communications will then repeat the sync words every 25 milliseconds, using the master clock frequency and its internal counter. As the communications cycle is now defined, the two sync words will be transmitted immediately following the MCS to shearer message.

**4.4.6 ECM Communications Processing** - A block diagram of the functional flow that takes place in the ECM communications microprocessors is presented in Figure 4-23. The operations that are performed have been separated into 6 basic routines. Two of the routines deliver data words to be transmitted and read data words from the receiver electronics. The other four routines manipulate data between memory locations, format words for transmission, and strip out data from words received.

Each of the routines has two entry points, one for the initial entry in which initialization of that routine takes place, and a second entry point for all subsequent entries until that routine is



NOTE: TIME ARE IN MILLISECONDS (MS), AND ONE COMPLETE CYCLE=25MS

Figure 4-22. Serial Data Line Timing Cycle

completed. Thus, the transmitter routine has initialization entry point designated by 1 and subsequent entries enter at 2. Similarly, the other routines are entered initially at numbers 3, 5, 7, 9 and 11, and second and all subsequent entries into routines use numbers 4, 6, 8, 10, and 12 until the particular routine is satisfied. The variable TR is used throughout to cause return to either transmit or receive routines so it is set equal to 1 through 4. The variable F is used to cause return to the data manipulating routines and takes on values 5 through 12.

The communications processor is capable of operating at a higher rate than the input/output device, which is a Universal Asynchronous Receiver Transmitter (UART). The UART takes 8 bits of parallel data and shifts it out serially for transmission, and receives serial data, shifting it into an 8 bit register where it is then read in parallel by the communications processor. At the serial bit rate chosen (40 K bits/sec), the communications processor can perform approximately 90 program executions during the time that one 8 bit word (byte) is being received or transmitted. The operational flow is thus structured to loop through the manipulative functions continuously, with a test provided within all loops that checks whether a transmit or receive operation is due. After a transmit or receive request comes on, it is sufficient to assure that the request be answered before about 90 additional program steps take place. This buffering capability of the UART allows considerable freedom in programming of the communications processor.

A complete program sequence as shown in Figure 4-23 is described below. First, TR is set to 1 and F is set to 5, and the program starts at 5. The program is thus set to start a transmit cycle while it is transferring data from the MPCC memory to the communications section of memory (from MPCC RAM to COMM RAM). The transmit routine is entered only when a flag representing Transmitter Holding Register Empty (THRE) is set, and the receive routine is entered only when the Data Available (DA) flag is set. Tests for these flags are made inside all the data manipulating routines, so the initial program start must enter one of the data manipulating routines (F=5 through 12).

Starting at 5, the program sets starting addresses for data transfers, then sets F=6 so that subsequent returns will step through memory until the routine has moved all data required from MPCC RAM to COMM RAM. The second step in this routine transfers one byte of data from one location in memory to another. A test is then made to see if the routine is complete. If it is, F is set to 7, which is a command to now start formatting data for transmission. If the routine is not complete, a test is made to see if a transmit mode or a receive mode is in progress, i.e., if TR is 1 or 2 (TR < 3). Since TR=1, the THRE flag is tested; if true, program sequences to TR, which is now 1. The flow then enters the transmit routine at

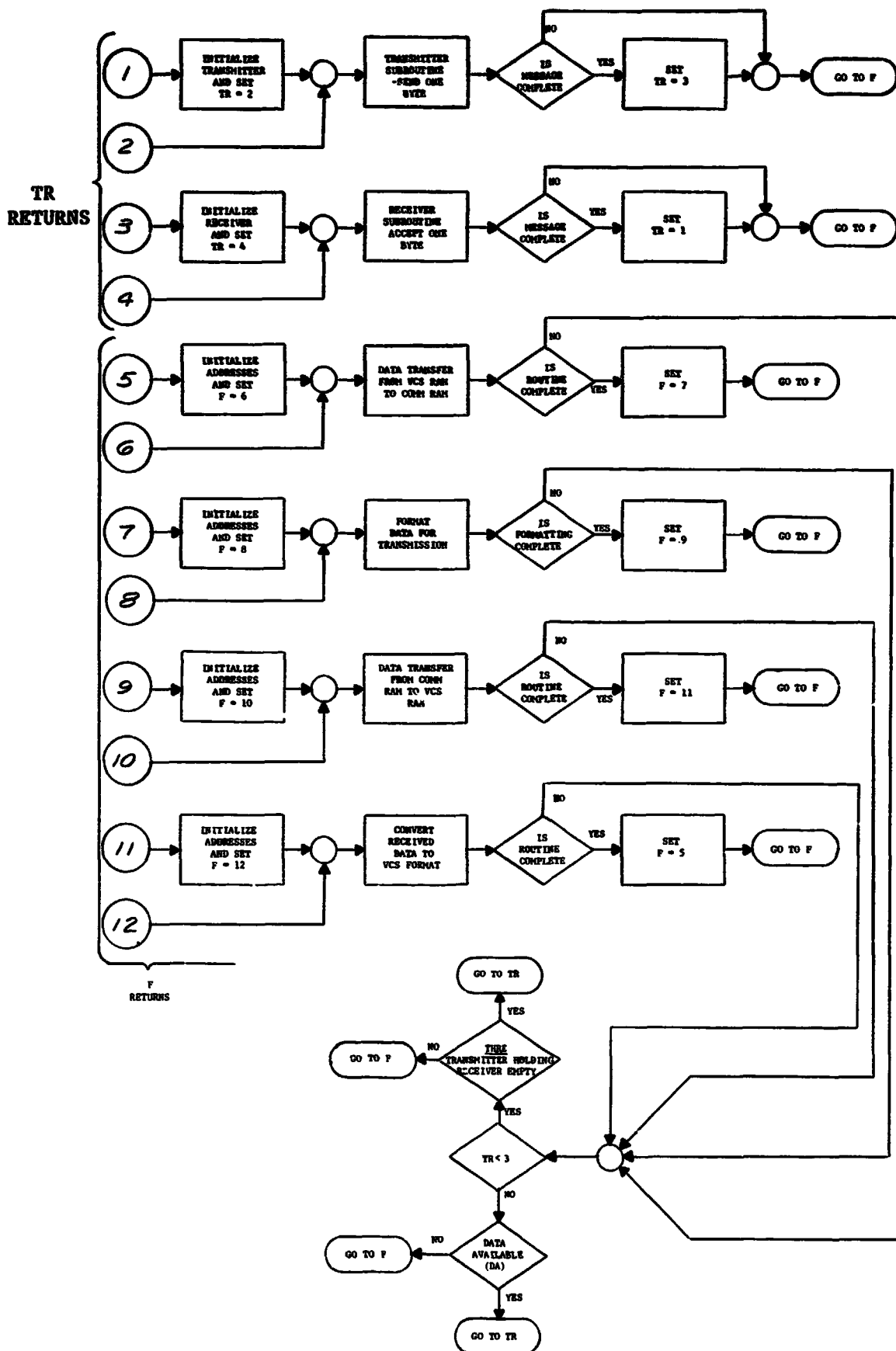


Figure 4-23. ECM Communications Flow Diagram

1, initializes the routine by setting a memory address pointer at the first byte to send and sets TR=2 for subsequent bytes. The routine then sends one byte to the UART and resets THRE. Next a test is made to see if the message is complete, i.e., is this the last word of the message. If true, TR is set to 3, which is the code to start receiving. If not true, TR remains at 2 and control returns to F. At this point, F is still 6, so control returns to the first data transfer routine, which moves another byte from MPCC RAM to COMM RAM. The transmit or receive flag is checked, and if no flag is present, control cycles back through F (now 6) and moves another byte from MPCC RAM to COMM RAM. Since about 90 microprocessor program steps can be completed before the transmitter is ready for another byte, and about 7 program steps are required to complete one data transfer loop about 12-13 bytes can be transferred in memory while one byte is being transmitted or received.

When this data transfer routine is complete, F is set to 7 to start the next routine, which formats data to the form desired for transmission. The first entry to this routine sets starting addresses for data to be read, formatted and stored, then sets F=8. One byte of data is formatted and stored for later transmission, then a test is made to see if the routine is complete ( $KF < KM$ ). If not completed, the transmit or receive ready flag is tested. If no flag is set, the routine forms another byte and stores it for transmission. This routine continues until the complete message to be transmitted has been prepared, while continuously checking for transmitter or receiver flags. When the formatting routine is complete, F is set to 9 to start the next data handling routine.

The routine to transfer data from COMM RAM to VCS RAM, and the last routine which converts incoming data to forms usable by the control microprocessor operate just like the other two data handling routines. They each loop through program steps until completed, and check for transmit/receive flags on every loop.

Figures 4-24 through 4-27 shows more detailed flows for the six routines mentioned above plus one special routine which is used to update ECM calibration. The entry to the special routine is caused by special code words from the MCS, which are handled in the receiver routine. The receiver routine is discussed below in some detail followed by the lead in to the special routine that updates the VCS.

Figure 4-24 shows the flow diagram for the receiving data routine, with initial entry at 3 and subsequent entries at 4. On the first entry, a byte is read from the UART into the communications processor D-register. There are 3 error checks made on incoming data: parity error, overrun error, and framing error. These error flags are sampled by an OR gate, and if true, the byte is ignored and control exits to another function. If no read error occurs, the D-register

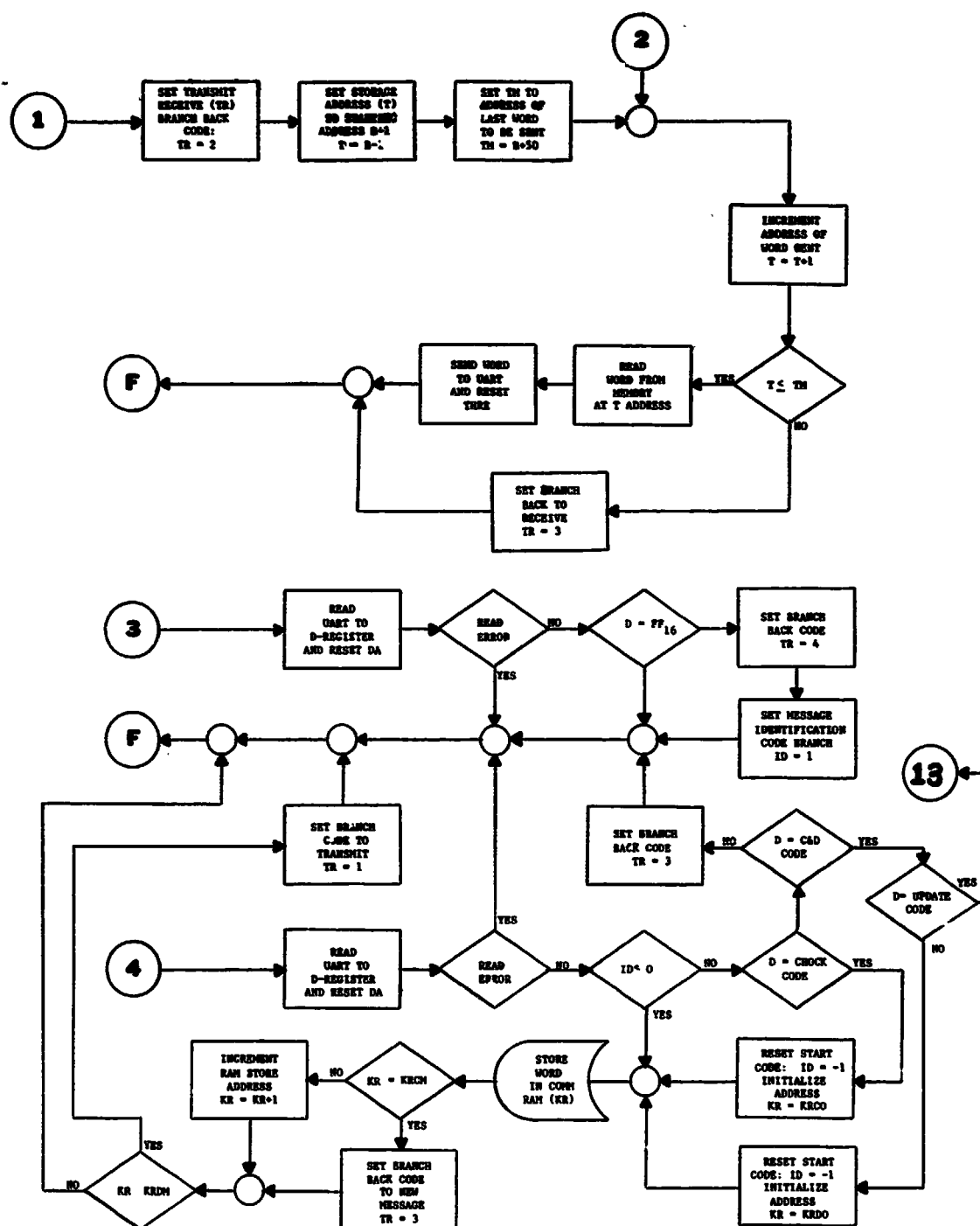


Figure 4-24. ECM Transmit and Receive Flow Diagram

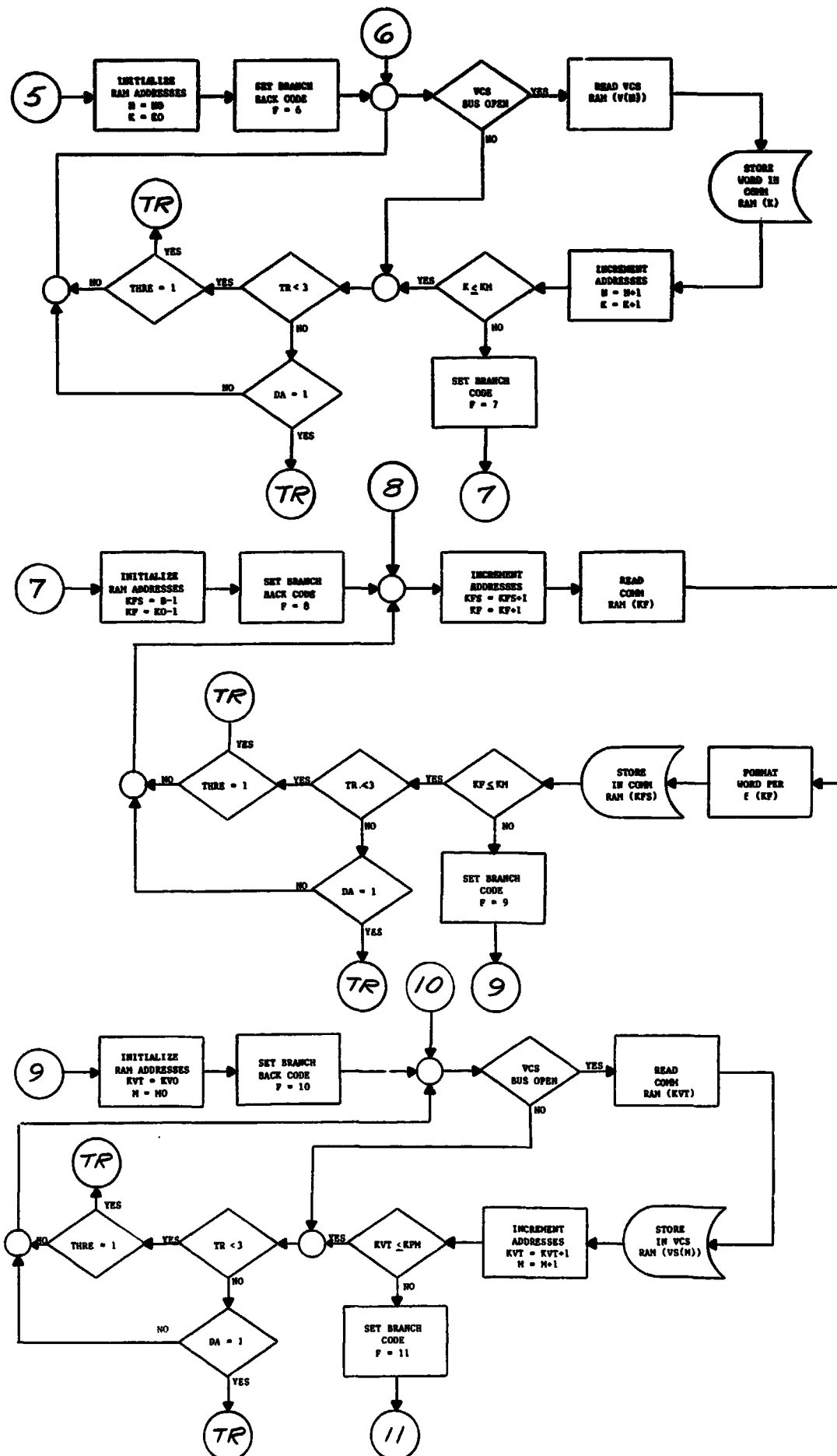


Figure 4-25. Data Handling Flow Diagrams

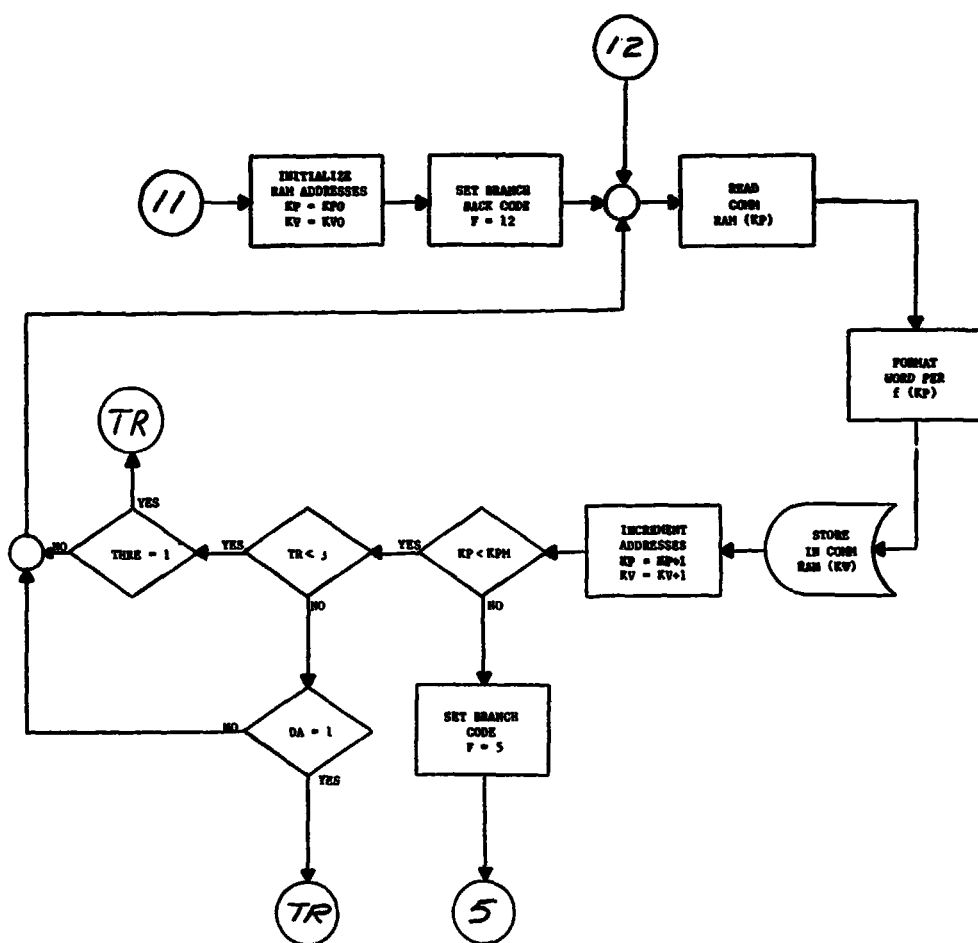


Figure 4-26. Data Formatting Flow Diagram



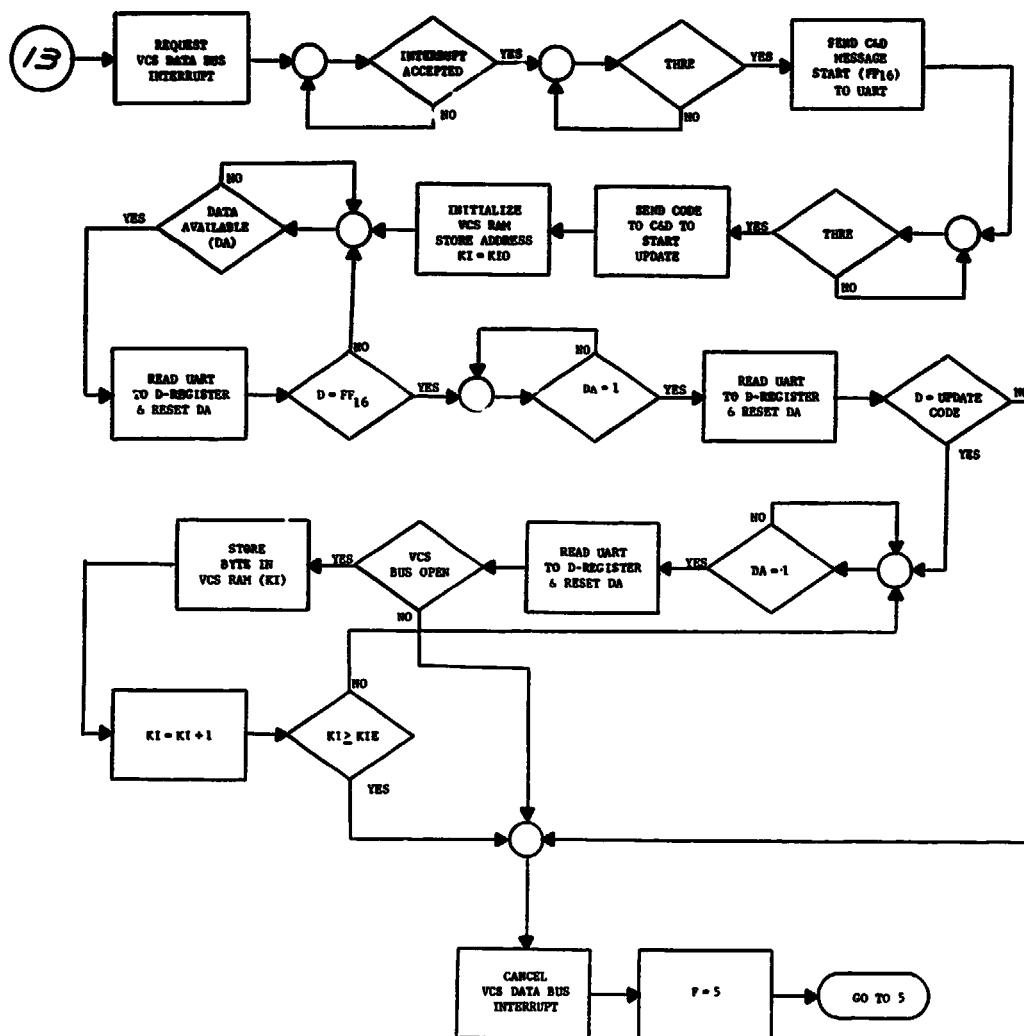


Figure 4-27. ECM Parameter Update Communications Flow Diagram

contents are compared to the start message code, which is FF<sub>16</sub> (11111111). The program is exited immediately until a start code is obtained. When a start message occurs, TR is set to 4, and an identification required message is set by setting ID=1. This code indicates that the next word received must be an identification code.

When entry occurs at 4, data is read from the UART to the D-Register. Again, if a read error occurs, program control exits, if not, ID is checked to see if an identification code is expected. If a code is expected, it is tested to see if it is a Roof Support or a MCS code. If it is a Roof Support code, the initial address for storing data is set for roof support data and ID is set to -1. If it is a MCS code, it is also checked to see if it is a special update message code. If it is not an update, but a normal MCS message, the initial address for storing data is set for MCS data, and ID is set to -1. Once identification of the message is established, subsequent words received are stored sequentially until the given message is completed. When a normal C&D message is completed, TR is set to 1 for transmission mode.

When the receiver routine examines the identification word and finds that it is a special update signal from the MCS, the routine exists to 13, which is discussed in the following section.

**4.4.7 VCS Communications Update** - There are a number of parameters within functions performed in the ECM MPCC which require updates as mining conditions or sensor characteristics change. To allow for a data load that will define these parameters whenever desired from the Digital Address System (DAS) on the MCS C&D panel, a separate receive routine was generated as shown in Figure 4-27.

To allow the communications processor MPCC to operate in parallel without interference on the data bus, a bus isolator is placed between the two systems. The isolator is under exclusive control of the MPCC and cross communications can only occur when the isolator is open. During normal data shuffling between memories that is done by the communications processor, the bus isolator is opened periodically by the control processor and a signal is sent to the communications processor to use the bus as needed. This procedure is shown in all the data handling routines as a test on "VCS BUS OPEN."

In this special routine, it is necessary to cause the isolator bus to be opened and remain open until the complete update message is received. This is done under the assumption that all control functions are suspended anyway until the update is accomplished.

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The update routine is entered at 13 when an update code has been received from the MCS. The communications processor immediately sends an interrupt request to the control processor, requesting that the MPCC bus be opened. The control processor must respond by suspending all control functions in an orderly fashion, then opening the data bus and remaining in a pause mode until the interrupt request is cancelled by the communications processor at update completion.

The communications processor then tests to see if the interrupt request has been acknowledged. The communications processor then sends a message start code (FF<sub>16</sub>), followed by a start update code to the C&D panel. The communications processor then initializes the storage address locations in control processor RAM where the update data is to be stored. The communications processor then reads the UART for input bytes from the MCS. The first byte must again be a start message, the second byte must be an update code, then subsequent bytes are received and stored directly in MPCC RAM locations until the update is complete. When the update is complete, the MPCC interrupt request is cancelled, and normal routines are re-established by setting F=5 and returning to entry point 5.

During the update procedure, the communications processor does not perform any other functions, which means it is idle for considerable portions of time as it is in a pause mode while waiting for bytes to be shifted into the UART register. The control processor simply waits for a cancellation of the interrupt request for the complete update time.

4.4.8 Voice Communications - An audio channel will be carried on the communications line in digital form, with high and low bits formed by frequency shift keying like the data channel but at a different carrier frequency. This will be done with a voice transmitter channel consisting of microphone, audio amplifier, an A/D converter, a frequency shift keyed modulator, and a summing amplifier or mixer to add the signal to the data signal before the line driver amplifier. The receiver channel consists of an active filter tuned to pass the two digitized voice frequencies, a frequency shift keyed demodulator, a D/A converter, an audio amplifier, and a speaker. Each subsystem within the longwall system where voice communications is desired will have similar input/output channels.

The A/D converter that will be used in the voice channel is a CMOS He55516 or equivalent, Continuously Variable Slope Delta Modulator (CVSD), which converts voice signals to serial digital data. Switching a logic level on a selector input allows the same unit to re-convert digital data into voice. This CVSD unit is optimized for 16 K bits/sec, and is usable down to 9 K bits/sec. Fidelity may be increased by using a higher frequency unit, the HC55532, which is optimized for

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32 K bits/sec, and is usable beyond 64 K bits/sec. The particular bit rate chosen will be set by a separate clock frequency on the data line. The communications clock will be located at the master control station.

This digitizing of voice technique was chosen to transmit the voice over the digital data line in order to take advantage of new technology developed for enhancing performance for a lower cost. This technique will provide a relatively noise free voice link through the line driver and cable used for the data link. Other techniques, such as FM are also available and could be transmitted through the data cable, however, for this preliminary design the digital technique was chosen.

4.5 Design of the I/O Subsystem - After the operational requirements, sensors and control devices were defined, the preliminary design of the I/O subsystem was accomplished. This subsystem or subassembly is configured to read and store the input from the signal conditioning. This stored or latched input data is read by the CPU, as required, for storage and use in its operational algorithms. This I/O subsystem is further configured to accept and latch data employed by the system control devices.

Figure 4-28 indicates the input data which is stored for use by the MPCC, as well as the output data stored for use by control and display devices. Review of this figure will indicate that there are 312 bits of data which is latched in 64, 8 bit words. This figure will also indicate the 64 bits required to output the control and display which is organized into 8, 8 bit words.

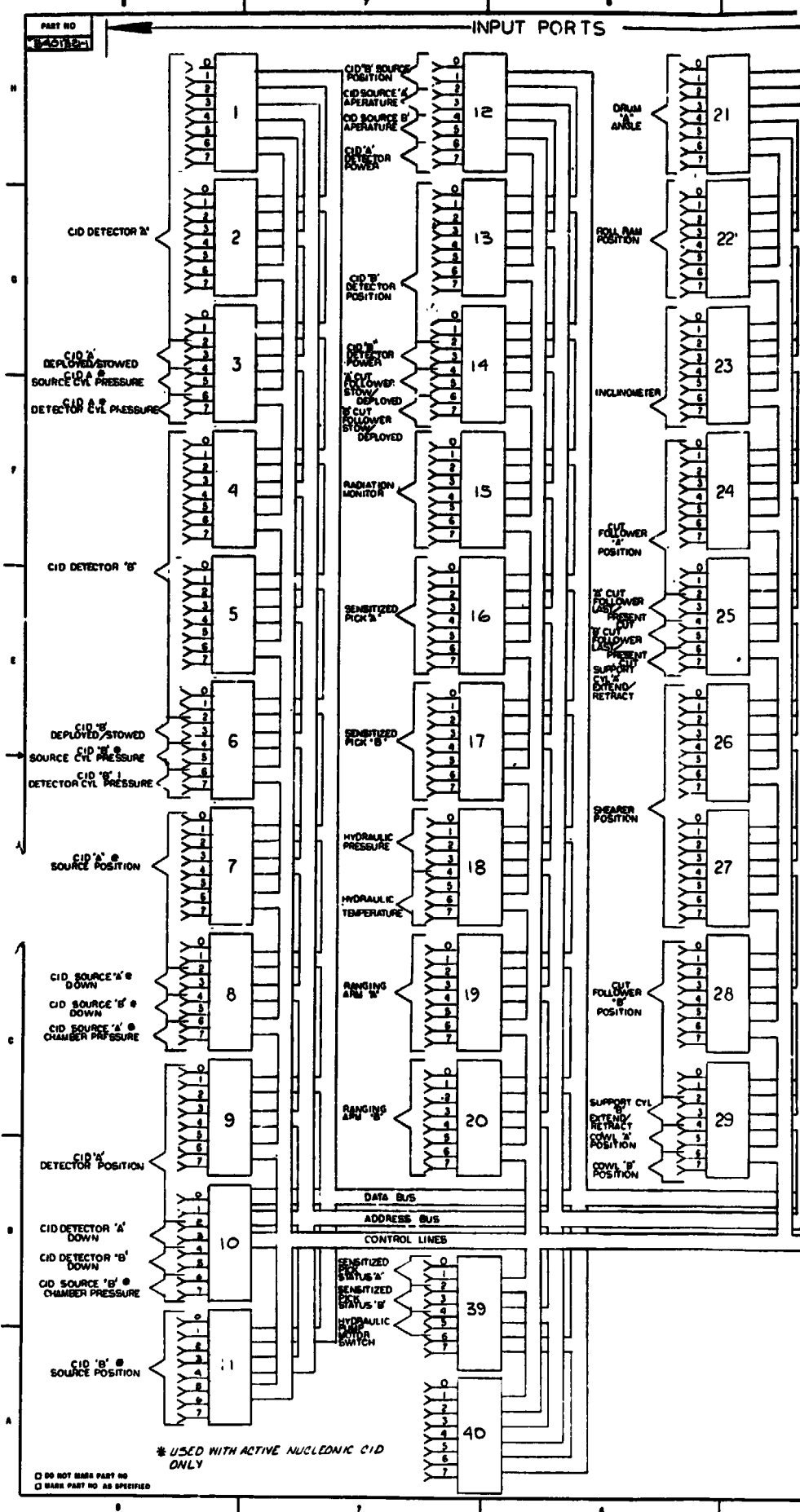
The select lines employed to select the particular 8 bit input/output ports are generated by the MPCC from memory address lines. These address lines address memory locations allocated for input/output ports. The strobe and latching of data into these ports is accomplished with the normal MPCC I/O select lines.

As with most of the other subsystems, CMOS technology has been selected for the same reasons previously supplied.

4.6 Power Supply and Power Distribution - The ECM of the long-wall shearer contains an explosion proof power supply box. All the DC voltages required for use in the system are generated in this box. The auxiliary battery pack, required to power radiation hazard indicators when shearer power is shutdown, is also housed in this box. It should be noted that when the passive radiation CID is employed the battery pack is eliminated from the system. The explosion proof box also contains solid state relays and darlington drivers, since these devices operate at "intrinsically unsafe" voltage levels.

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**4.6.1 Power Supply Circuits** - The Power Supply Block Diagram is presented in Figure 4-29. Primary 120 VAC 60 Hz power is obtained from a power panel on the shearer and fused at 5 amps. Since this primary AC voltage is susceptible to extreme fluctuation of up to 50% of nominal, an AC voltage regulator is incorporated. The AC output of the voltage regulator supplies 4 power supplies: 5 VDC/6 amp regulated,  $\pm$  12 VDC/2 amp regulated, 28 VDC/1amp regulated and 110 VDC/1amp unregulated.

The circuits which the regulated power supplies energize, are protected by overvoltage devices. Should these voltages surge to an unsafe level, due to a malfunction, the overvoltage protectors will clamp the outputs to near zero volts, thus protecting the associated circuits from damage.

Regulation of the 110 VDC power supply is not critical because it is used to energize electromechanical solenoids. All the power supplies are redundantly current limited to provide "intrinsically safe" energy levels. Therefore, the individual lines do not need to be handled with "permissible" cables. The 110 VDC may be an exception due to the high voltage involved. Equipment requiring 110 VDC may only be "permissible", requiring permissible interconnecting cables between the power supply box and the equipment. A 28 VDC battery pack is added to the power supply box if an active nucleonic CID is used. In case of shearer power shutdown, or 28 VDC supply failure, a switching circuit - also contained in the power supply box - allows the battery pack to supply power to the various radiation hazard detectors and audible alarm. The battery pack maintains its power through "trickle charge" by the 28 VDC power supply.

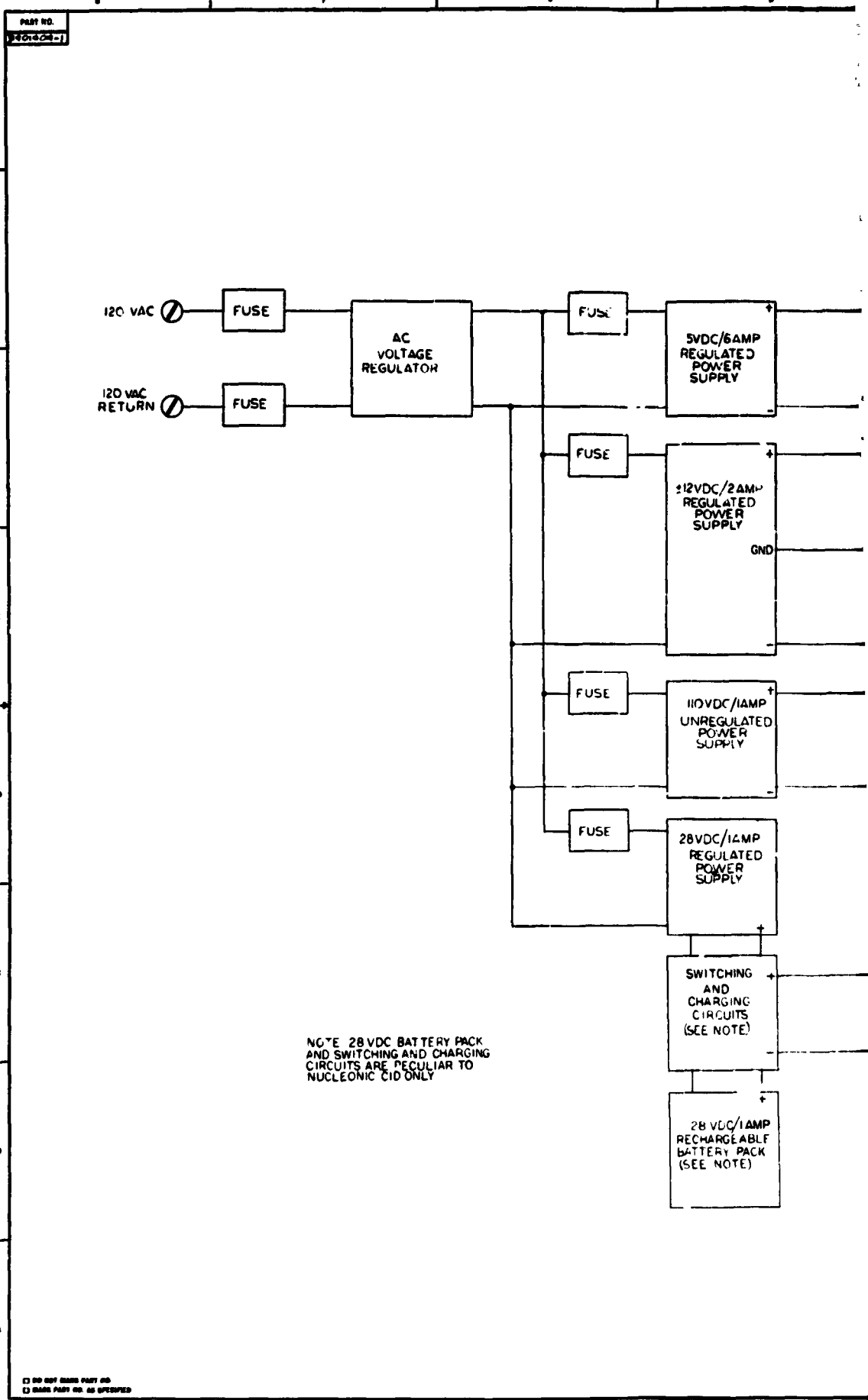
**4.6.2 Power Distribution** - A system power distribution diagram is shown in Figure 4-30. With the exception of the 110 VDC power, all the other supply voltages are routed via a single multiconductor cable from the power supply box to the ECM box. In the ECM box, the 5 VDC power energizes the signal conditioning electronics, input/output ports, main control computer, and communications. From the ECM box the 5 VDC power supply is routed to all the position encoders, at various locations on the shearer.

The  $\pm$  12 VDC power is routed to the ECM box to energize some of the signal conditioning electronics. From the ECM box the  $\pm$  12 VDC power fans out to the sensitized pick receivers and inclinometer.

The 28 VDC power is needed to energize CID detector electronics. The ECM signal conditioning electronics monitors the 28 VDC current provided to the CID detectors. Therefore, 28 VDC power is routed to the CID detector through the ECM box.

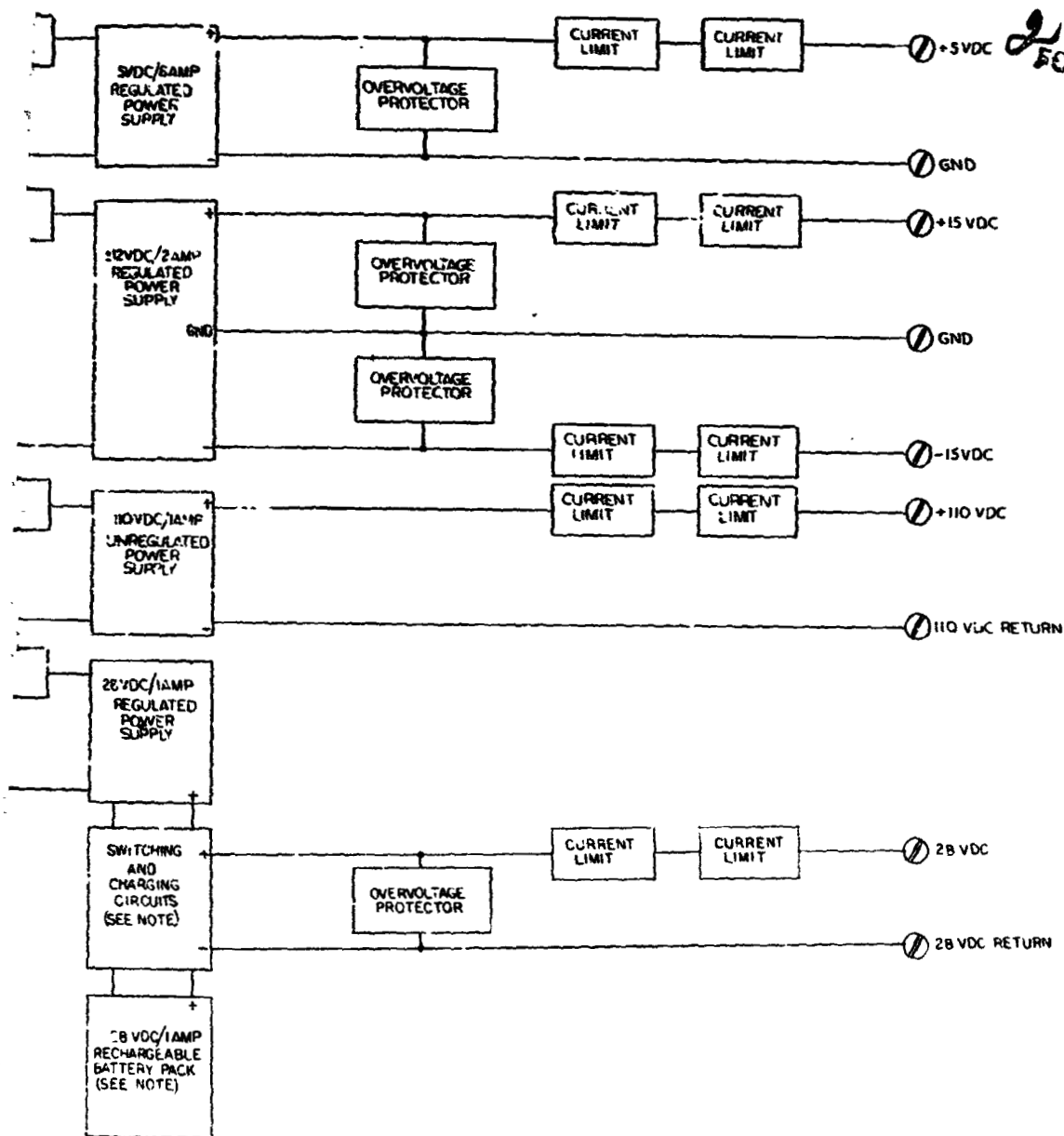
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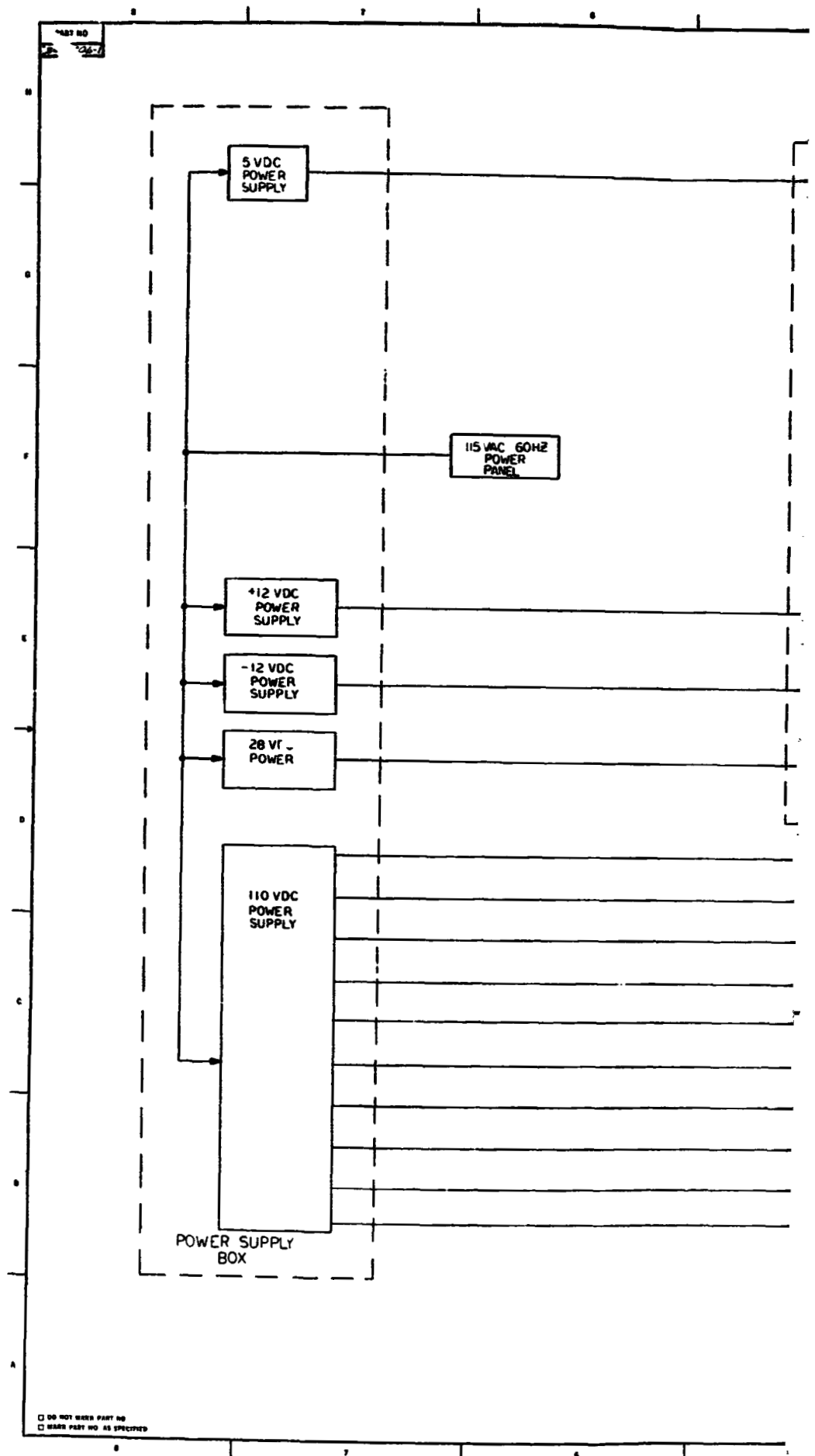
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LONGWALL VCS POWER SUPPLY BLOCK DIAGRAM 3901904	4-101
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Figure 4-29.  
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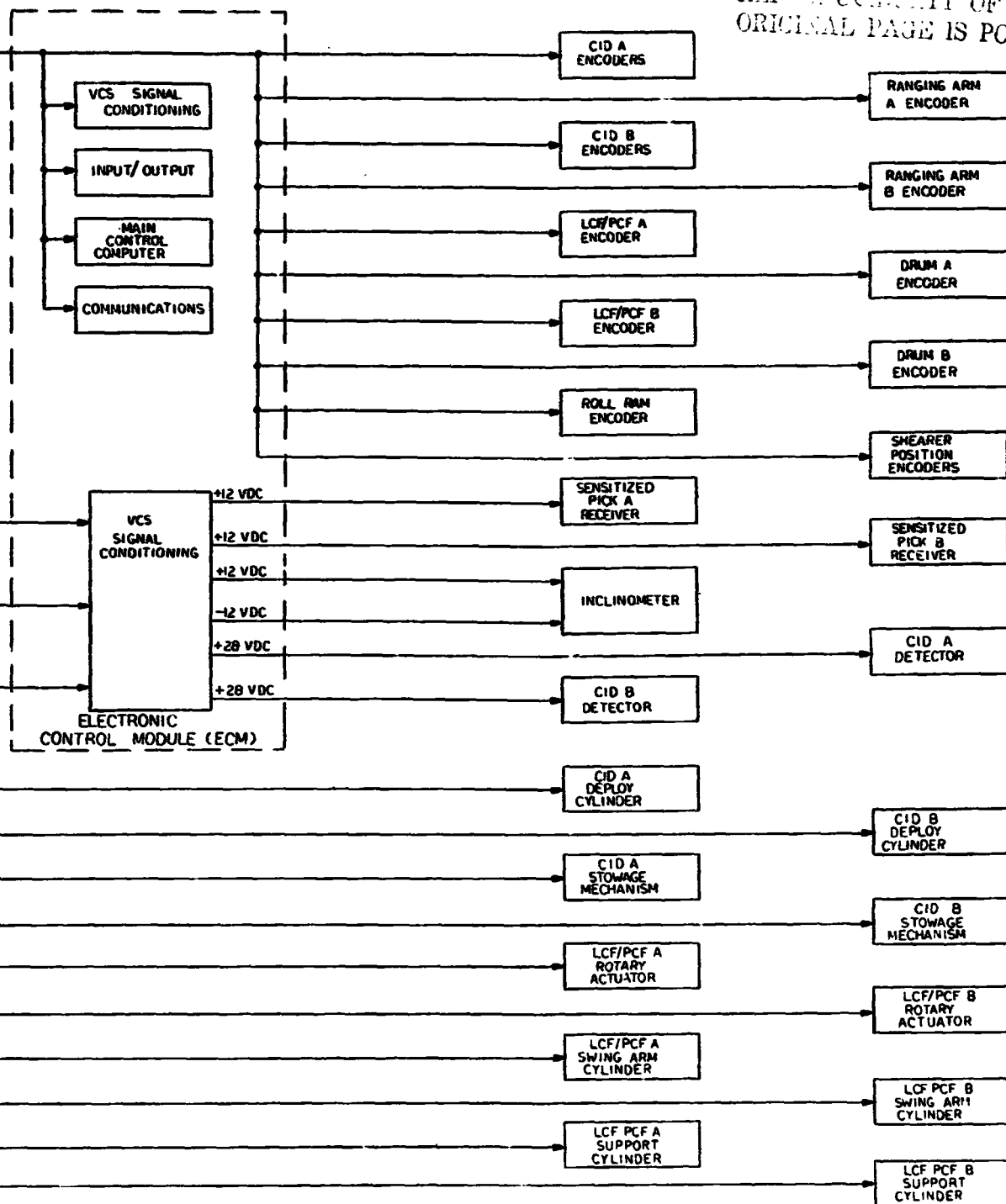
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Figure 4-30.  
4-102

The 110 VDC power lines are routed from the power supply to the various hydraulic cylinders utilizing electrical solenoids. Each individual cable from the power supply must be "permissible" type because 110 VDC is probably not "intrinsically safe" voltage level. All the power supply cables (5 VDC, + 12 VDC, 28 VDC and 110 VDC) emerge out of the power supply explosion proof box through explosion proof glands.

**4.7 Fabrication of ECM Electronics** - All of the ECM electronics, with exception of the power supplies electronics, is housed in a single enclosure referred to as the ECM (Electronic Control Module). The ECM contains the main processing and control computer, signal conditioning, input/outputs, and communications.

**4.7.1 Electronic Control Module** - The ECM enclosure is a 30 x 20 x 8 inches, Nema 12 oil and dust light steel enclosure. See Figure 4-31, Longwall VCS Electronic Control Module. The box needs not be "explosion proof" because all the electronics and the power that supplies it are "intrinsically safe." The front of the box, the ECM control panel, contains oil and dust proof switches and lamp indicators. The ECM control panel is used to manually exercise various shearer functions under the MPCC, as opposed to manually exercising the shearer by using shearer controls. The backside of the box has 11 industrial grade connectors of various sizes.

The VCS electronics inside the box are packaged on 4 x 8 wire-wrap cards (component boards). There are 14 cards that mate to a card cage assembly which is mounted on the hinged cover for easy access. The ECM box is mounted on top of the shearer, near its center. Cables from various locations on the shearer interface with the connectors on the back of the ECM box. See Figure 4-2, Longwall Shearer Electrical Cable Diagram.

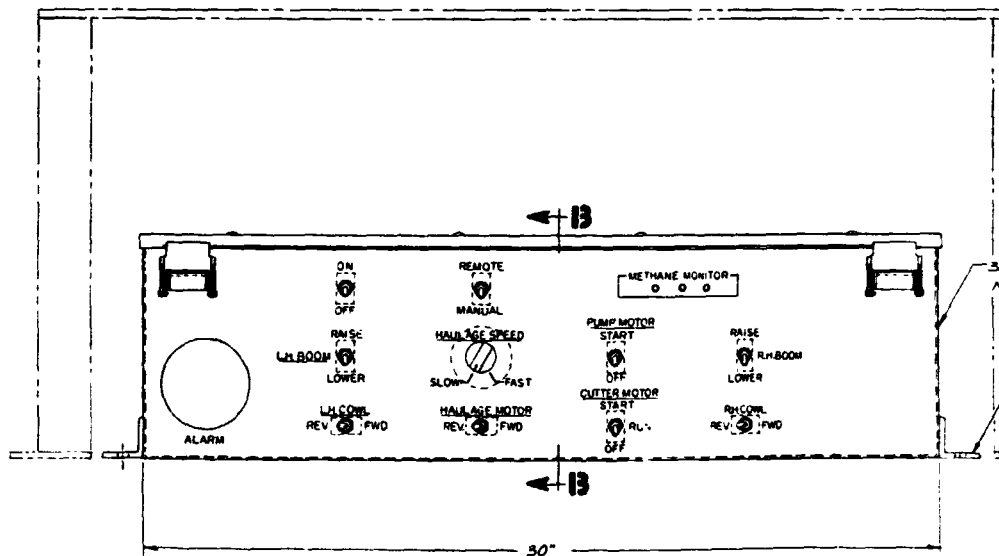
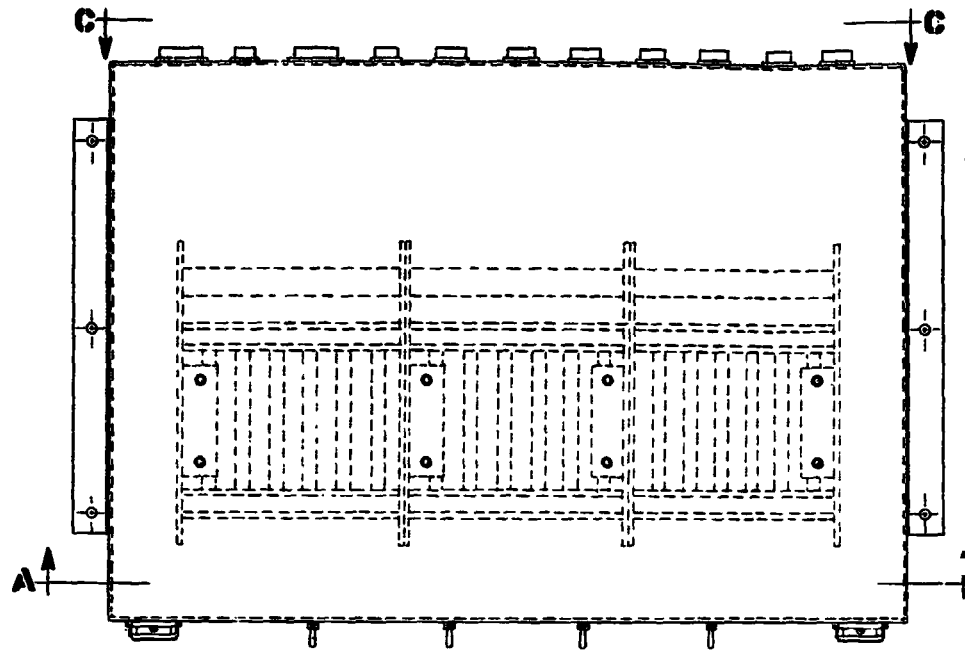
**4.7.2 Power Supply Box** - The power supply box is an "explosion-proof" enclosure. See paragraph 4.6. This box contains all the DC power supplies required for the VCS system. All the heat dissipating transformers are mounted for optimum heat transfer through the walls of the power supply. The solid state devices that dissipate heat are mounted on custom fabricated heat sink brackets which, in turn, are mounted to the walls of the power supply box.

All the cables to/from the power supply box are routed through "explosion-proof" glands. See Figure 4-30, Longwall VCS Power Distribution Block Diagram. The low voltage DC power supply cables are intrinsically safe, whereas the 115 VAC input and the 110 VDC output cables must be "permissible" types.

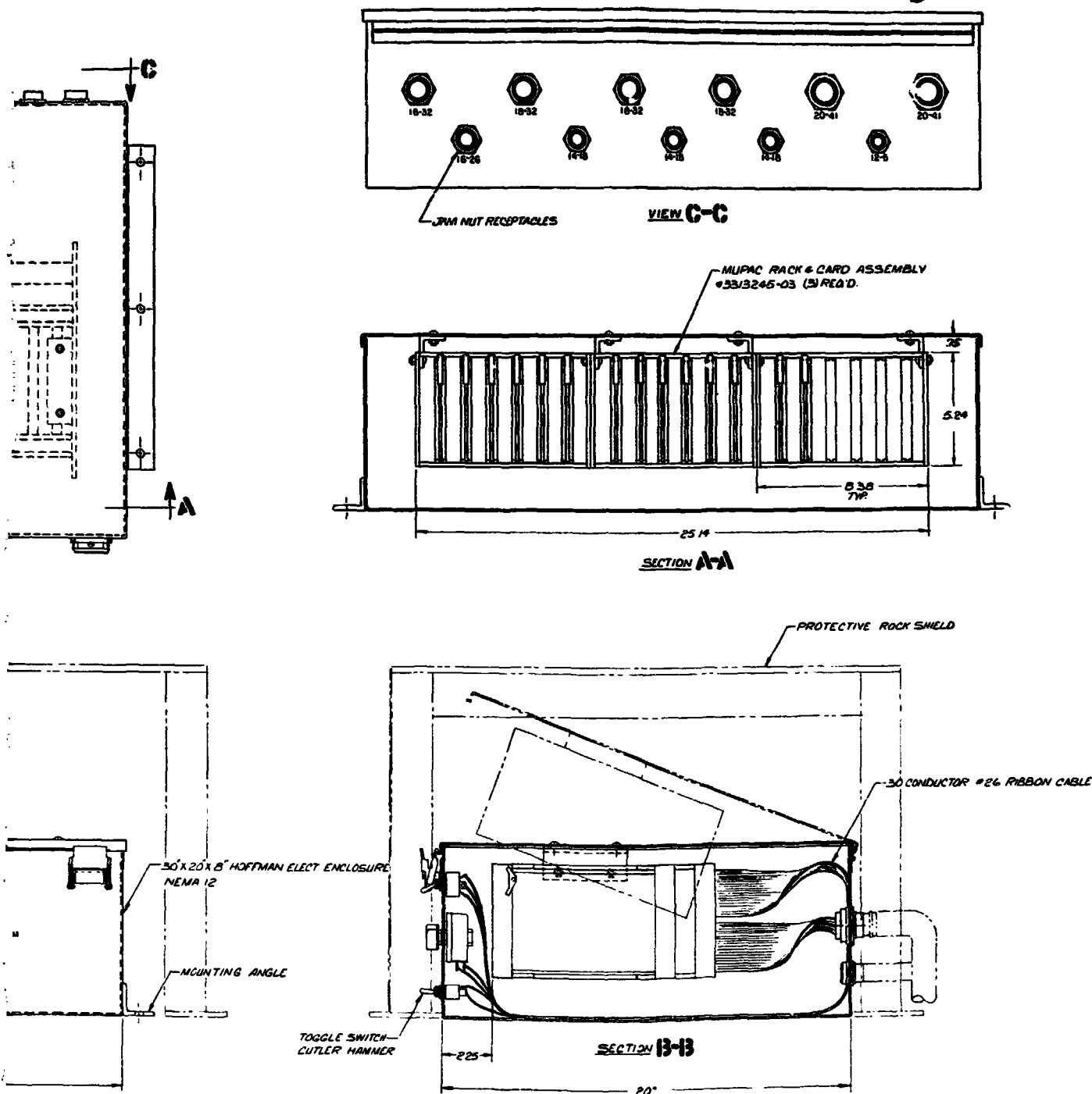
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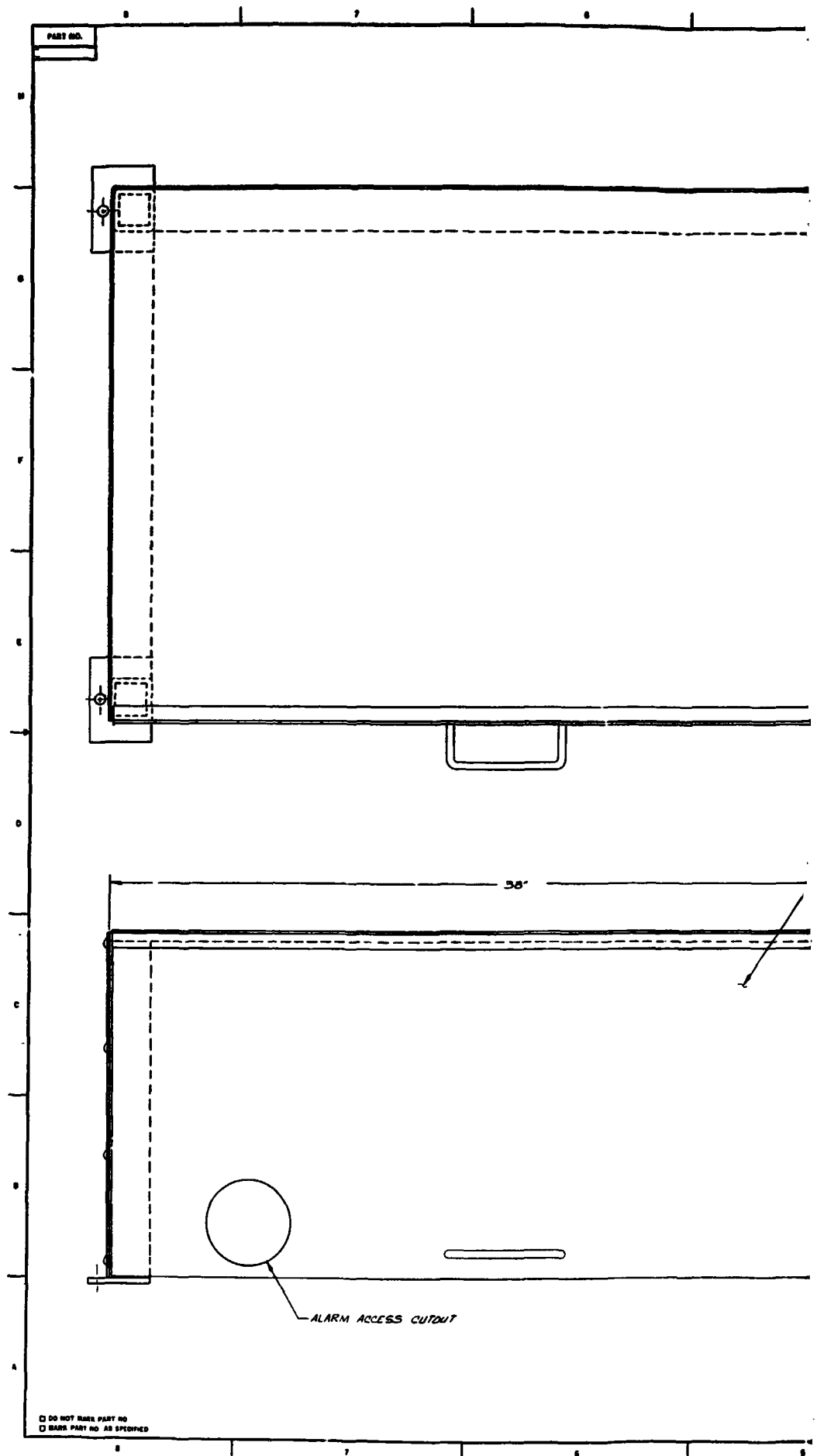
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Figure 4-31.

All cables, where applicable, are protected by metal channels, as well as flexible conduit. The power supply box and the ECM box, mounted next to each other, are protected from collision and projectiles by a metal canopy. See Figure 4-32, Rock Shield.

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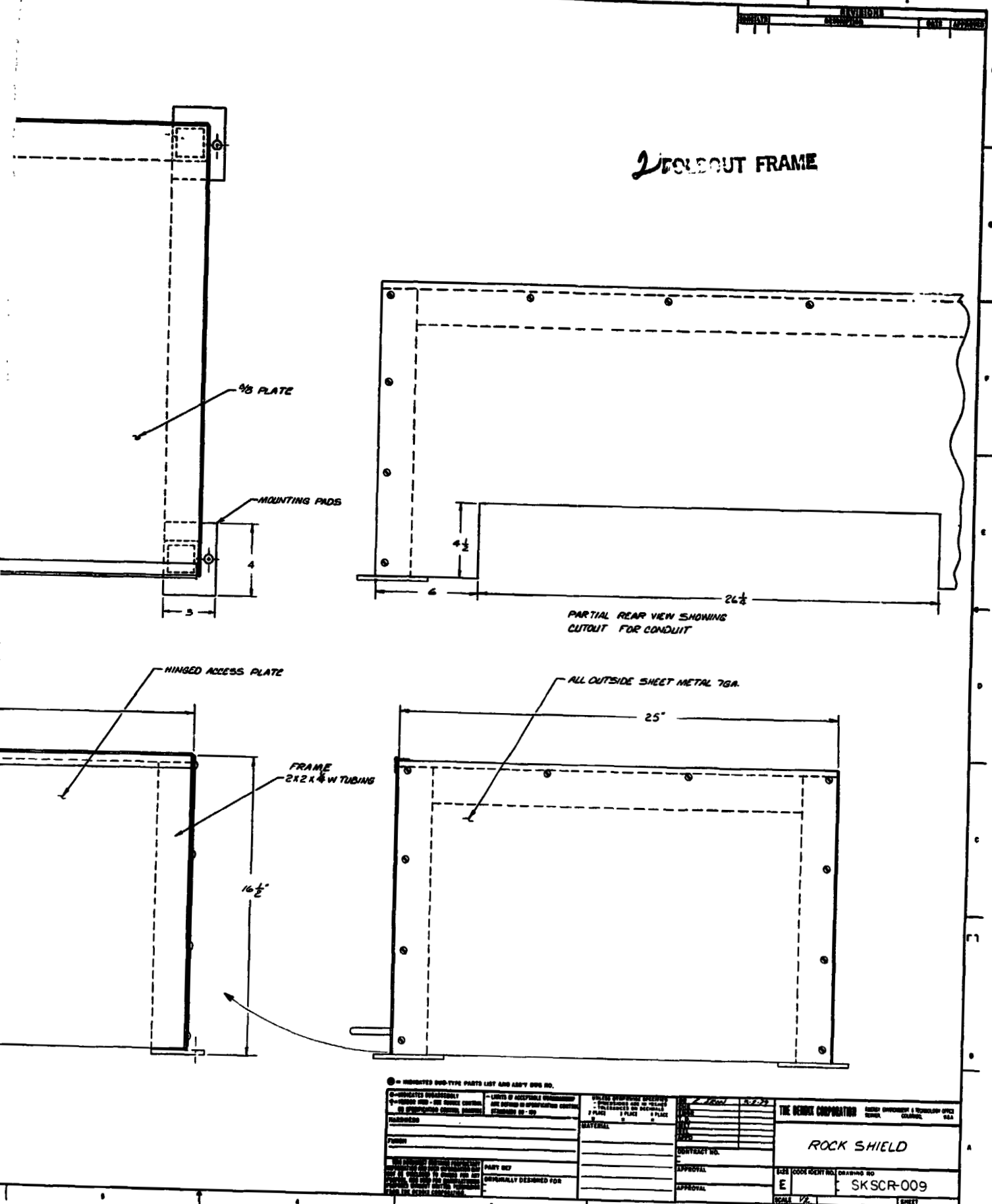


Figure 4-32.  
4-106

## 5. VCS MECHANICAL DESIGN

The mechanical deployment mechanisms for the last and present cut followers and the coal interface detector must be simple, rugged, and dependable. To simplify automation of the Joy Longwall Shearer, they should require minimum interfaces or modifications to the existing machine. The design of these mechanisms should achieve the greatest flexibility regarding various drum sizes, seam heights, and overlap conditions between top and bottom cutting drums. Each follower and the CID is required to have a vertical travel range of  $\pm 6$ " relative to the drum through as much of the ranging arm stroke as possible. To avoid damage due to the possibility of voids and overhanging slabs, the CID and followers should be able to fold out of the way when impacted by an obstruction.

The CID deployment mechanism must keep the CID in contact with the roof as close as possible behind the cutting drum cowl. It should also have a stowage position when not in use to provide clearance with the roof and protection from obstructions. If practical, the active and passive CID should be interchangeable on the support mechanism.

Both the last and present cut followers should remain above the center line of the shearer drum. Since they are located in close proximity it may be advantageous to combine them into one follower.

The following paragraphs outline briefly the evolution of the proposed final overall design. The types of Last Cut Follower (LCF), Present Cut Follower (PCF), and CID deployment mechanisms which are used throughout the subsequent overall designs leading to the final recommended one, are described first.

**5.1 Evolution of Proposed Design** - Two types of roof following mechanisms are used for the LCF and PCF in the following designs. Both use either a wheel or a shoe in contact with the roof. Using an angular encoder, the arm type shown in Figure 5-1 senses height as a function of the angle through which the follower arm swings. This follower has the advantage that it swings out of the way when impacted by an obstruction. In all the designs that use the arm type follower, the LCF and PCF are combined into one unit termed Last/Present Cut Follower (L/PCF). When shearer traverse direction is reversed the swing arm rotates  $60^\circ$ , the encoding head rotates  $180^\circ$  into the PCF position, allowing the arm to swing away from obstructions as it does when in the LCF position.

The telescoping canister type follower shown in Figure 5-2 senses height directly with a linear encoder. The canister must be provided with a spring loaded clevis to provide swing away protection from obstructions.

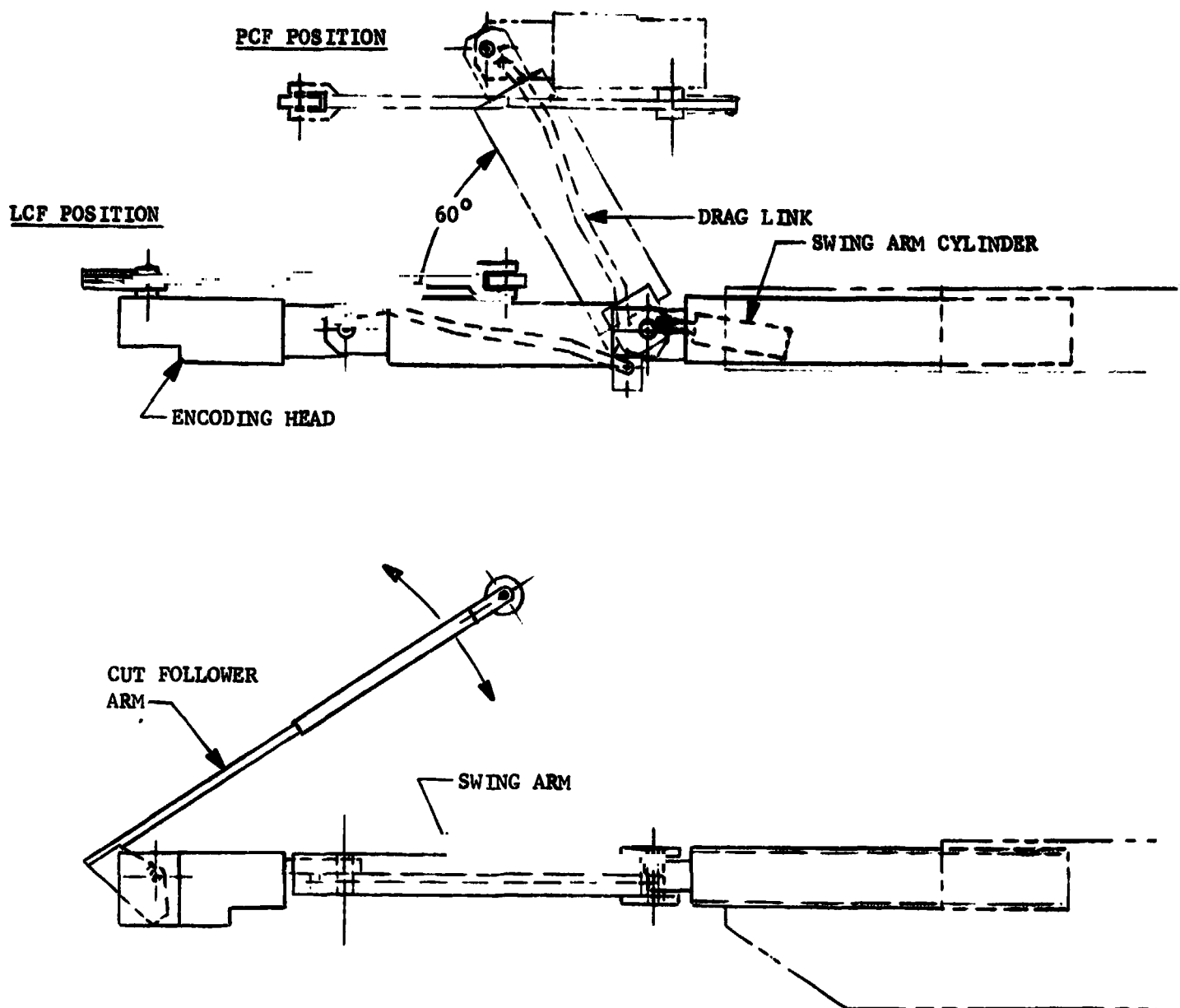


Figure 5-1. Swing-Arm Cut Follower

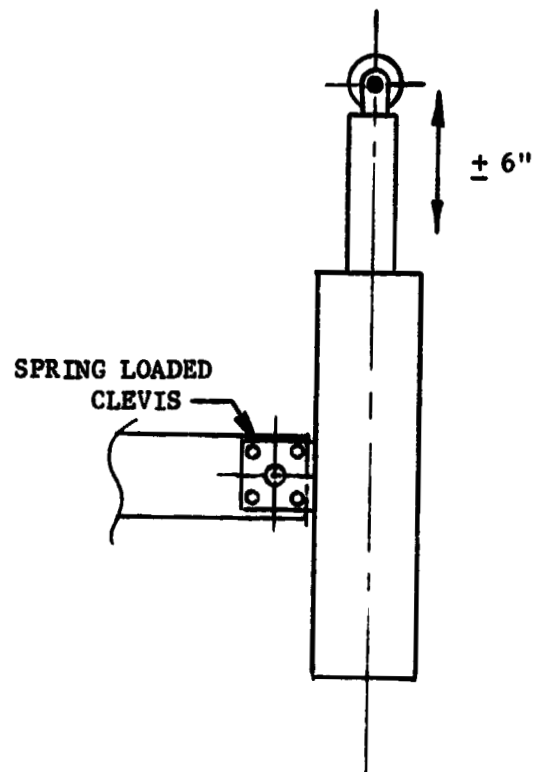


Figure 5-2. Telescoping Canister Cut Follower

Two types of CID deployment mechanisms are shown in Figures 5-3 and Figure 5-4. The parallelogram type, Figure 5-3, folds down as it is forced back, providing protection from obstructions. A hydraulic cylinder maintains an adjustable preload force against the roof and retracts the mechanism when not in use. Height is sensed by an angular encoder mounted to one of the pivot points.

The guide-way type mechanism, Figure 5-4, moves vertically on a track and senses height with a linear encoder. A hydraulic cylinder is again used for an adjustable preload force and for retraction. An additional mechanism must be used, however, to provide swing away protection. A rotary actuator returns the mechanism to its upright position after the obstruction has cleared.

The cut followers and CID deployment mechanism must be mounted on a platform or support which keeps them in position within their respective working ranges. The fixed platform shown in Figure 5-5 uses an arm type follower and a parallelogram type CID deployment mechanism. Since the platform is rigidly attached to the machine base, it is simple and rugged but allows the L/PCF and CID to follow the drum thru only +6" of its vertical movement. Hence relatively small shearer tilt angles will result in appreciable linear motion of the platform requiring large linear motion of the follower if it is to remain in contact with the roof. In addition, if the shearer tilts up, the sensors could be wrecked against the roof.

To resolve this situation, the platform could be powered up and down by a hydraulic motor and screw jacks as shown in Figure 5-6. This design, however, would require a complicated servo system to control platform movement and would not maintain the CID at a constant horizontal distance behind the drum.

To avoid the servo system and simplify vertical movement, the long pivot arm platform shown in Figure 5-7 was proposed which uses a mechanical linkage to follow drum movement vertically. The platform rotates thru a small angle about a simple pivot, and a guideway near the CID takes the torsional load for the long beam. The present cut shift cylinder allows the platform to be raised when the drum is in the trailing position and the PCF is to be used. This design still retains the disadvantage that it does not maintain the CID mounting distance behind the cutting drum constant.

The drum centerline support platform shown in Figure 5-8 follows the drum horizontally and vertically thru its full travel. It incorporates the canister type followers and parallelogram CID mechanism. In the horizontal position, shown in Figure 5-8, maintained by a constrained chain locked by a rotary actuator, the CID and LCF are in their respective operating positions. In the vertical position,

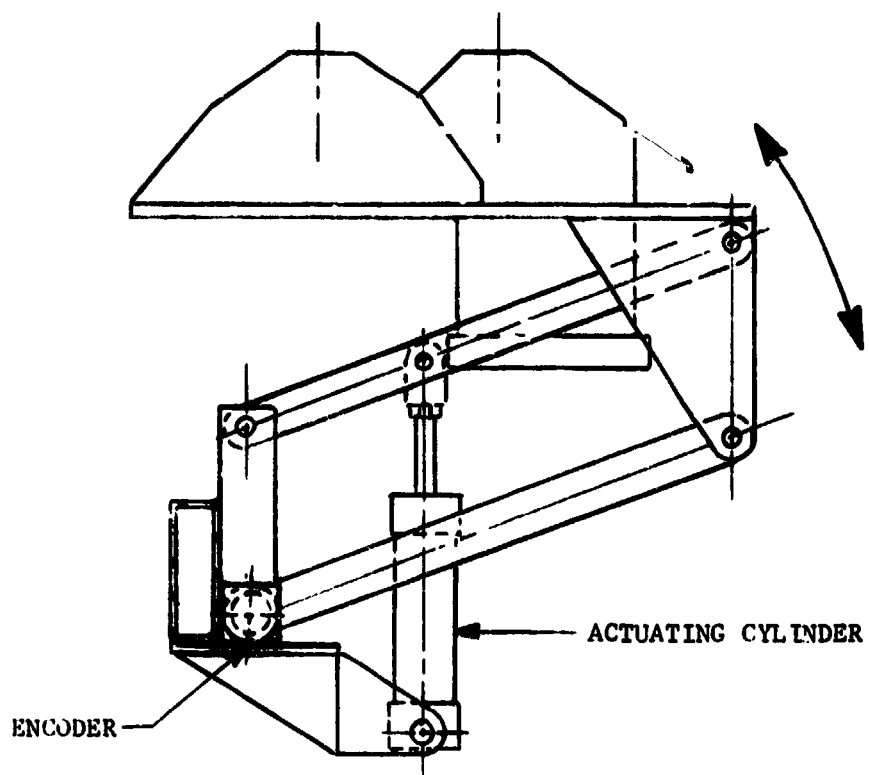


Figure 5-3. Parallelogram CID Deployment Mechanism

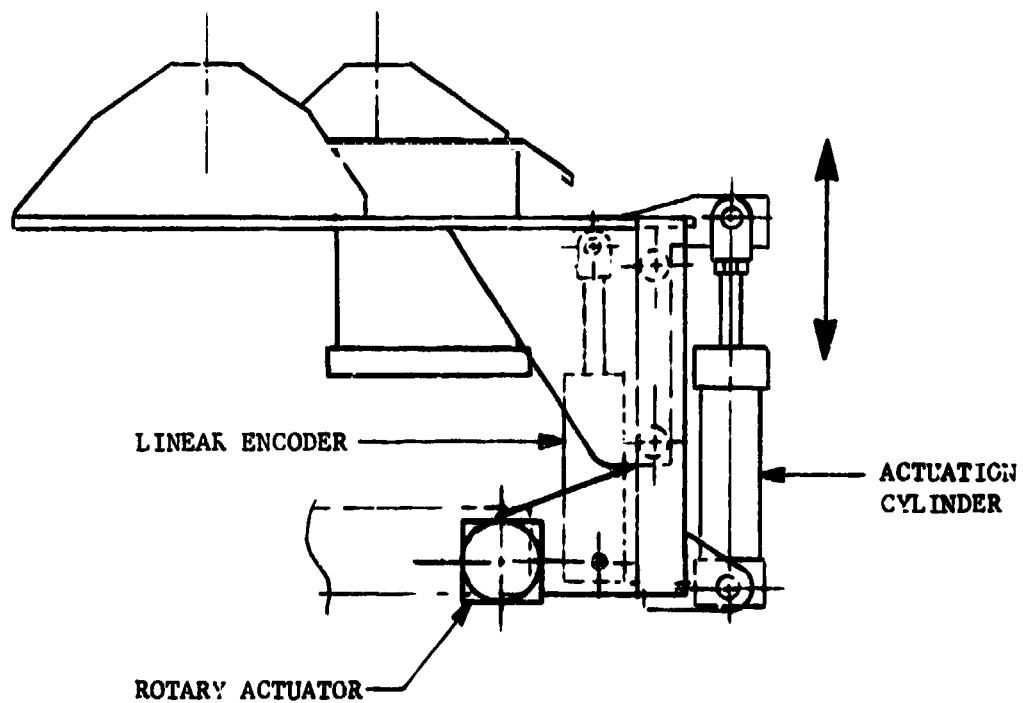


Figure 5-4. Vertical Guideway CID Deployment Mechanism

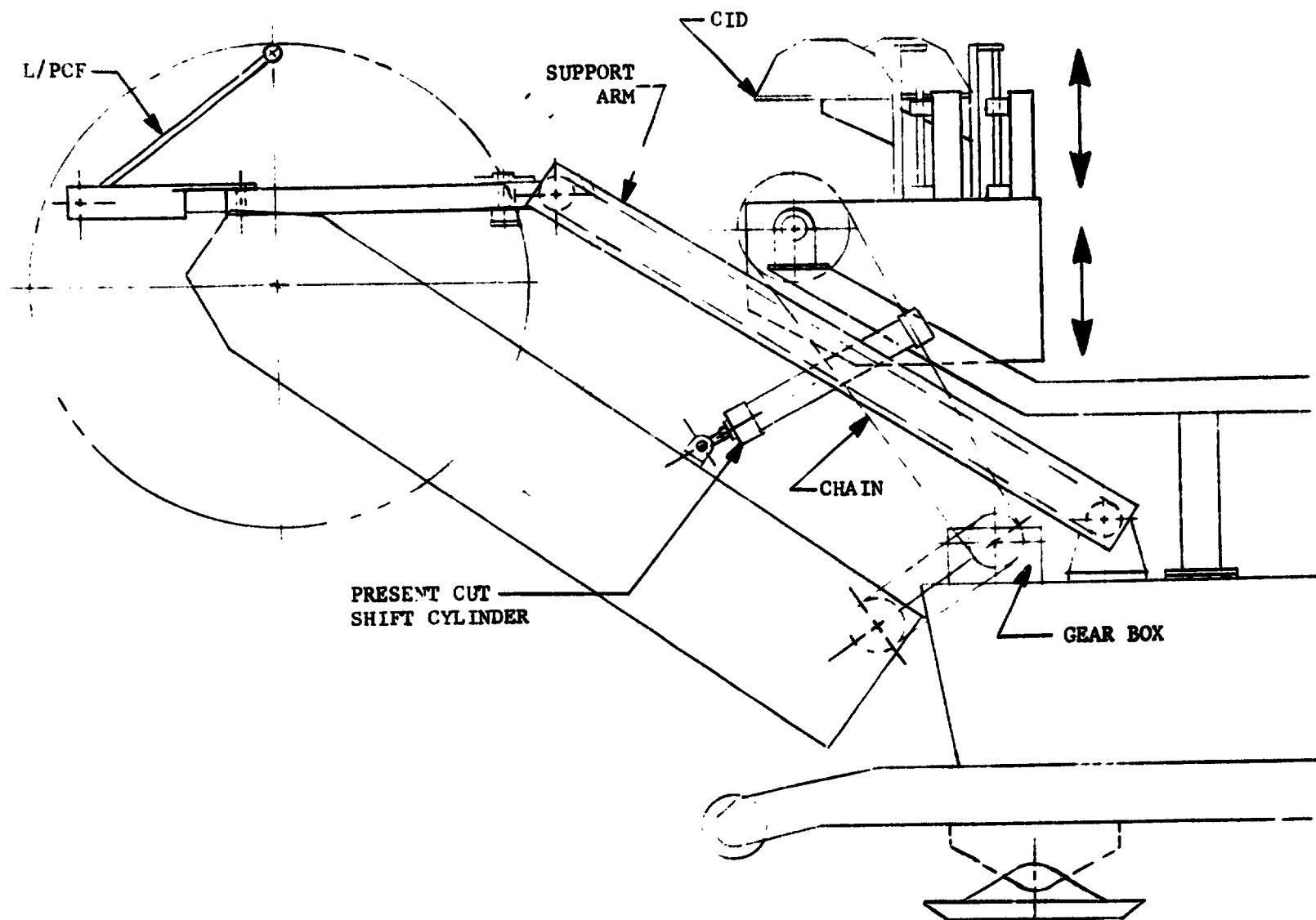


Figure 5-5. Fixed Platform

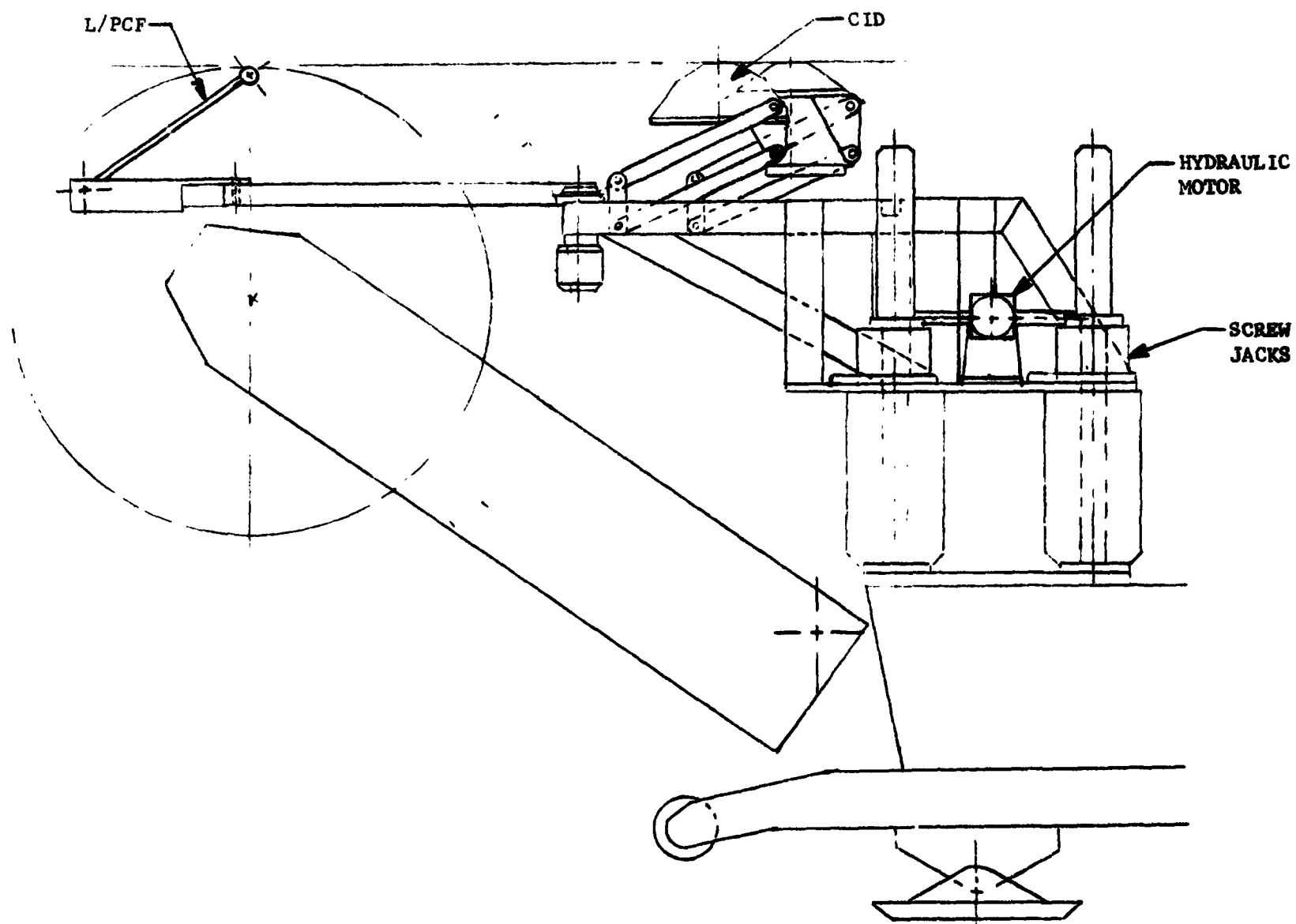


Figure 3 6. Powered Platform



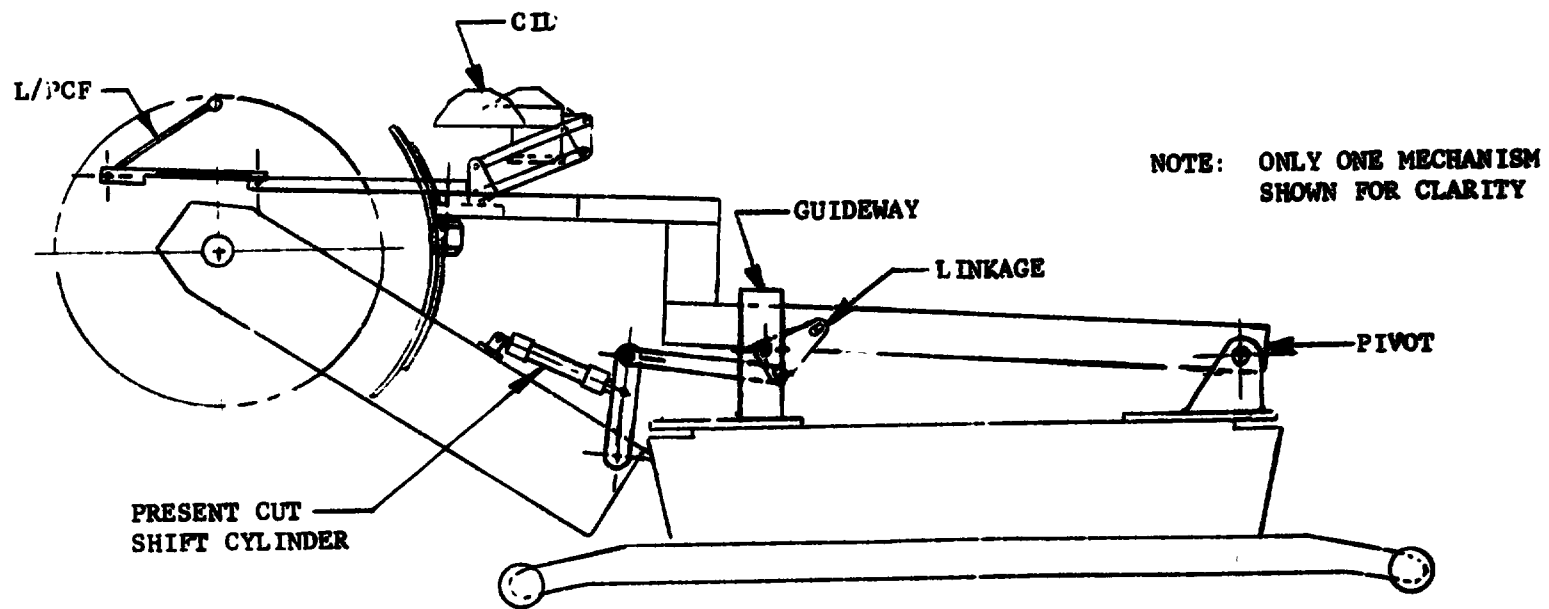


Figure 5-7. Long Pivot Arm Platform

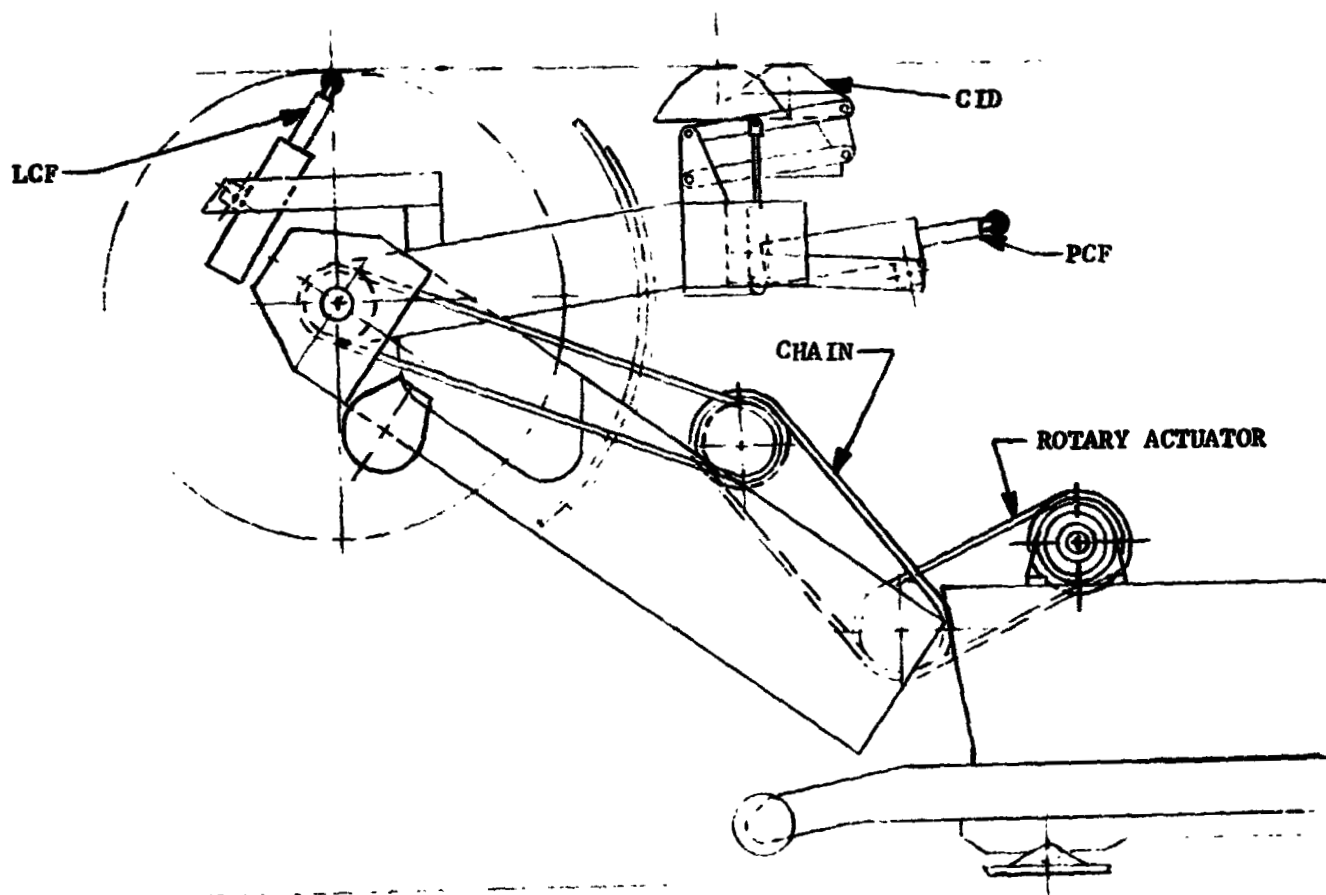


Figure 5-6. Drum Centerline Support Platform  
(Horizontal Position)

shown in Figure 5-9, achieved by rotating the actuator, the CID and LCF are stored and the PCF is in its operating position. Due to the CID mechanism that must swing over the drum and clear the cowl, the range of seam heights and overlap conditions that can be accommodated are very limited. Also the cowl motor would have to be relocated to avoid interference with the support arm.

The design shown in Figure 5-10 is quite flexible regarding seam heights and overlap conditions and allows the L/PCF to follow drum movements horizontally and vertically. It uses separate supports for the arm type L/PCF and the guideway type CID mechanism. The L/PCF is supported by an arm that forms a parallelogram with the ranging arm, the present cut shift cylinder being the fourth link, allowing the L/PCF to follow the drum exactly. A constrained chain within the support arm keeps the swing arm horizontal. The cylinder is extended when the ranging arm is in the trailing mode allowing the PCF to remain on the roof.

The CID deployment mechanism is mounted in another guideway platform which follows the drum up and down. This is accomplished with a rack and pinion to which is attached a chain and a gearbox which amplifies ranging arm rotational movement. Besides being rather complicated, this design does not maintain the CID mounting distance behind the cutting drum constant.

**5.2 Proposed Design of Sensor Deployment Mechanisms** - The proposed final design, Figures 5-11 thru 5-24 combines the advantages of the previous designs. It follows drum movement horizontally and vertically and enables the shearer to be used in a wide range of seam height and overlap conditions; see Table of Range and Adjustments, Table 5-1. The mechanism is also adjustable to operate with the full range of drum sizes available from Joy and does not require a servo system. Although the baseline recommendation is the passive radiation CID, the mechanism for the active nucleonic CID will be discussed first since it is more complicated.

Figure 5-11 shows the two sets of sensor mechanisms required to automate the Joy Longwall Shearer. The forward mechanism is in the LCF position with CID deployed. The rear mechanism is in PCF position with CID stowed. These incorporate the combined last/present cut follower and parallelogram CID mechanisms mentioned earlier.

The support parallelogram, constrained by the support cylinder, follows and remains parallel to the ranging arm thru its forward cutting position range to within  $5^{\circ}$  of horizontal as shown in Figure 5-12. The top member of the parallelogram, the horizontal support, remains horizontal and in a fixed position relative to the drum center.

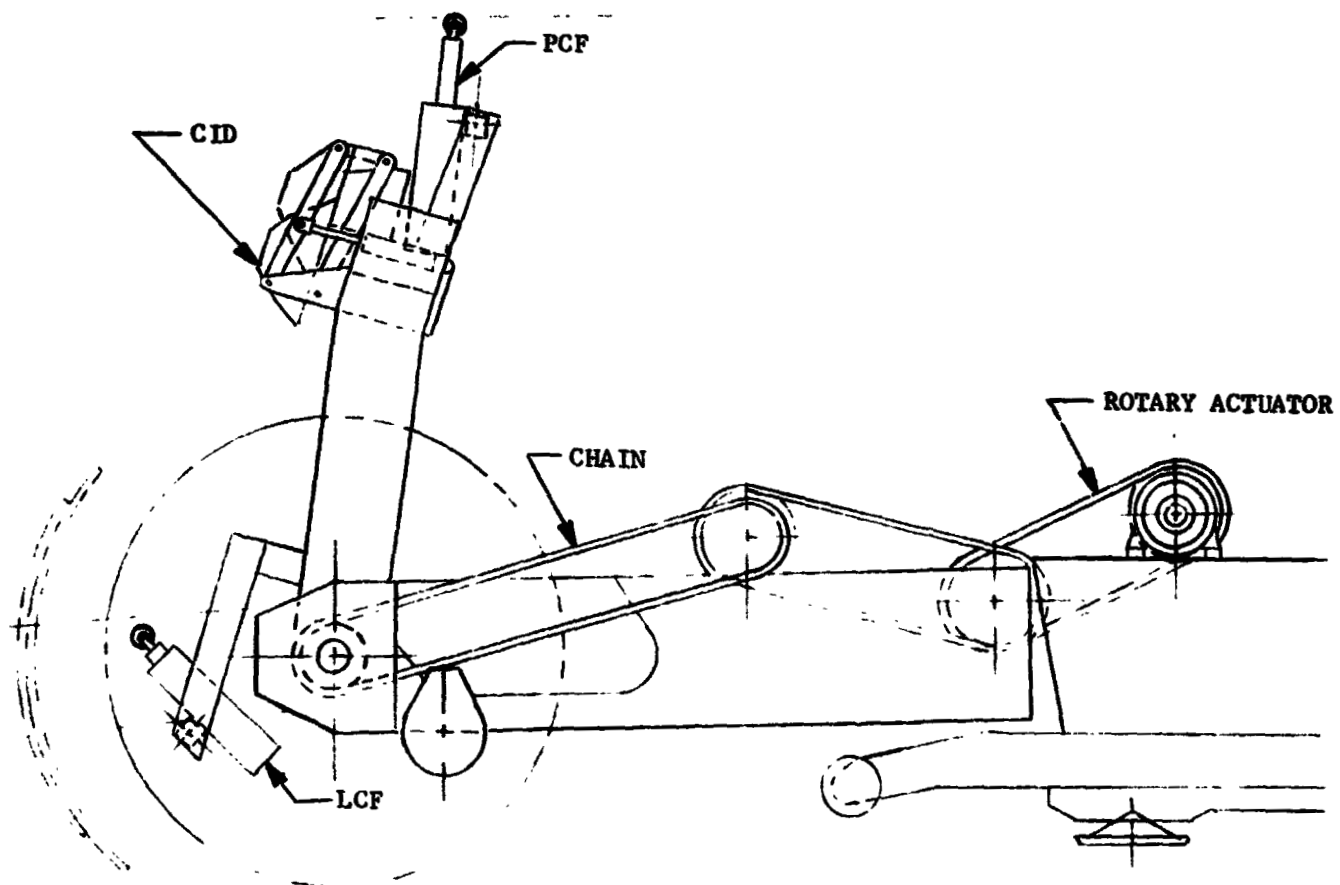


Figure 5-9. Drum Centerline Support Platform  
(Vertical Position)

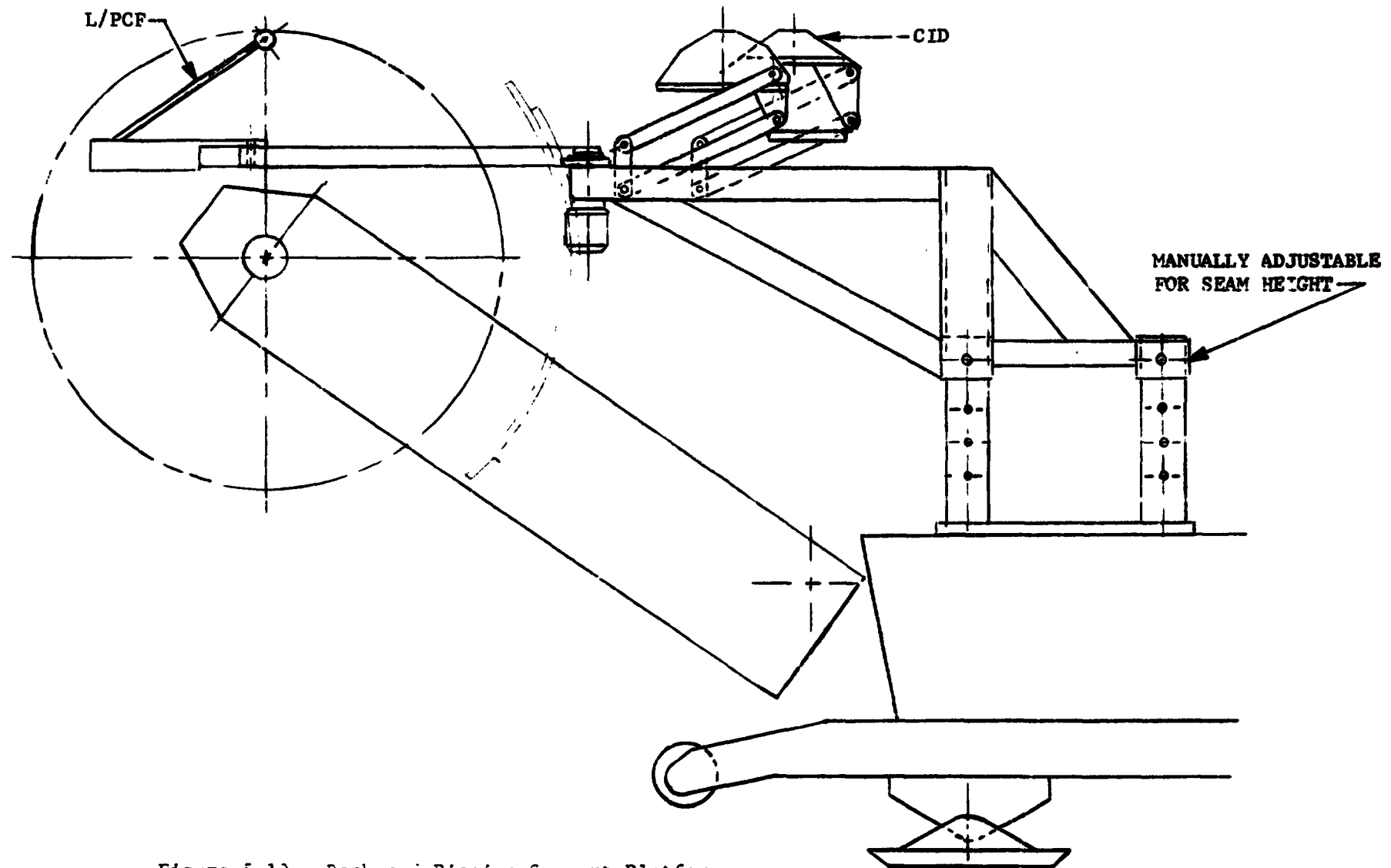
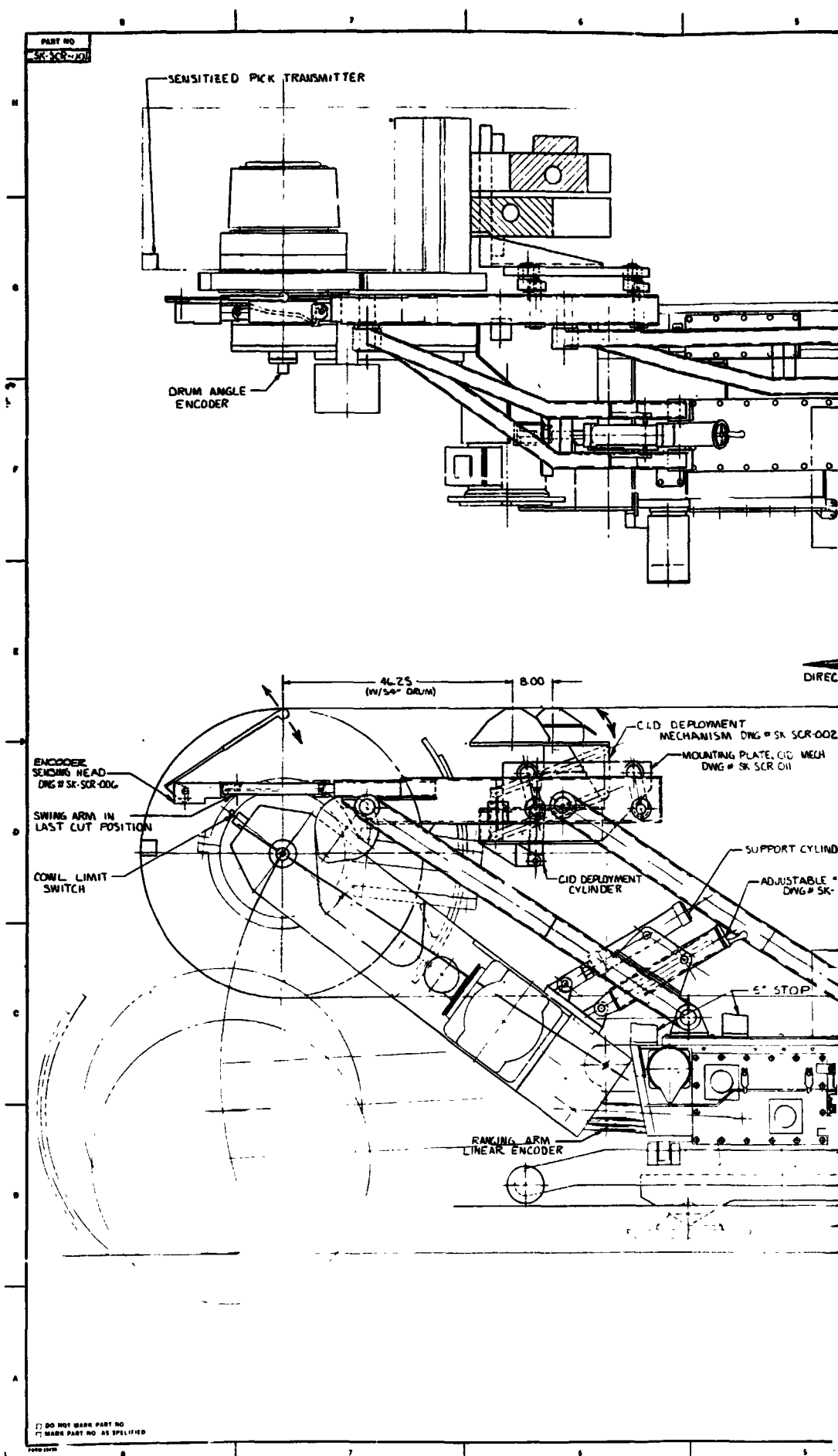
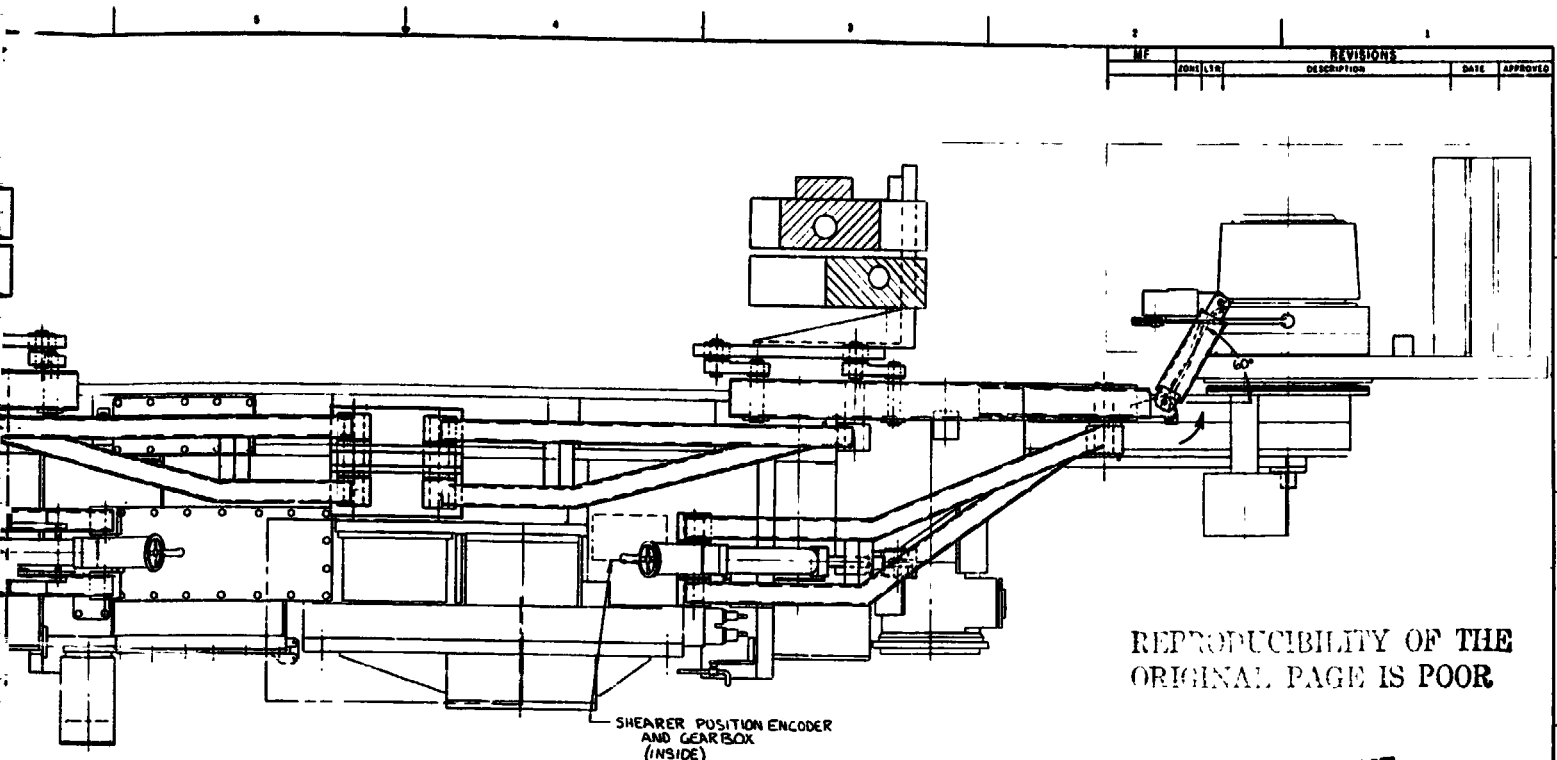


Figure 5-10. Rack and Pinnion Support Platform

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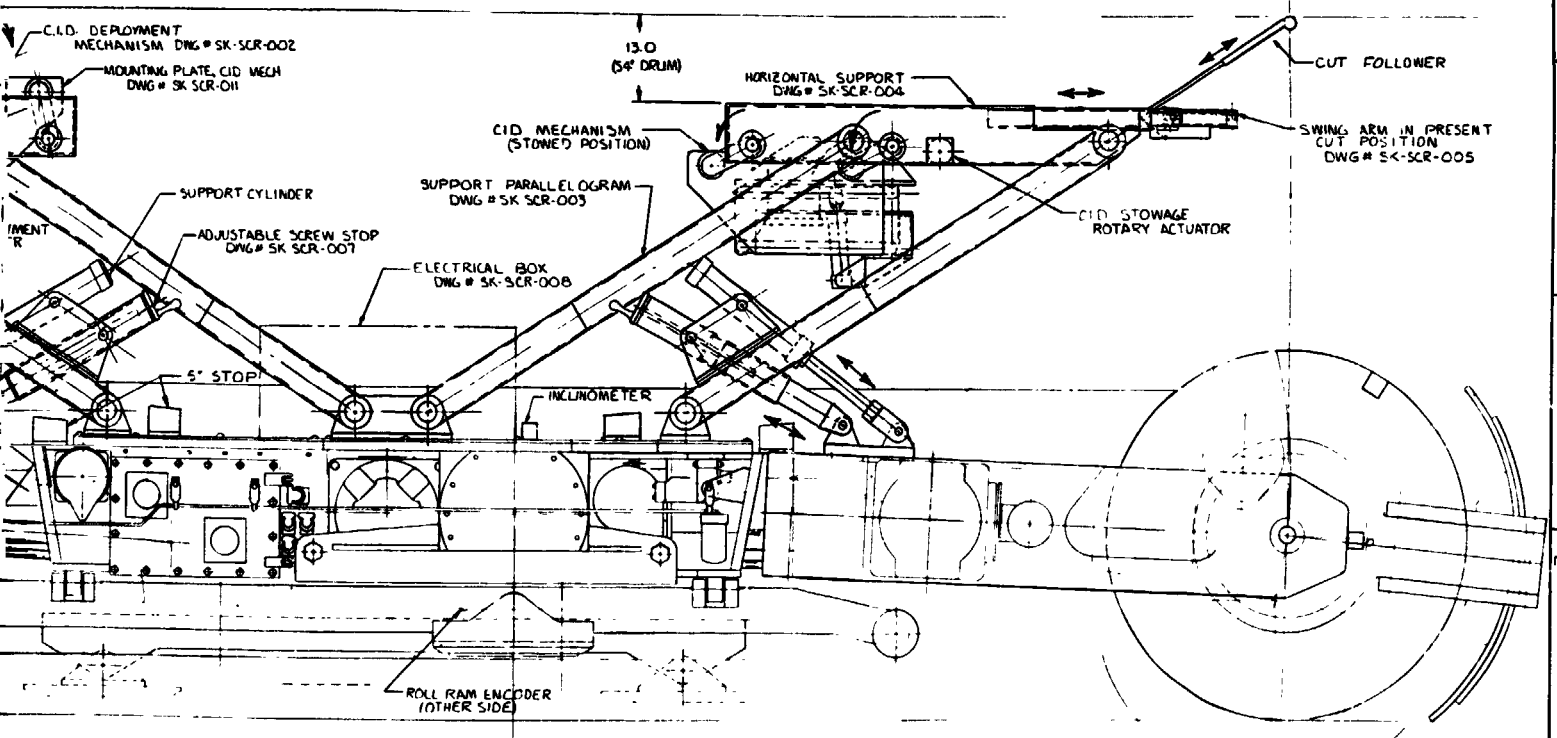
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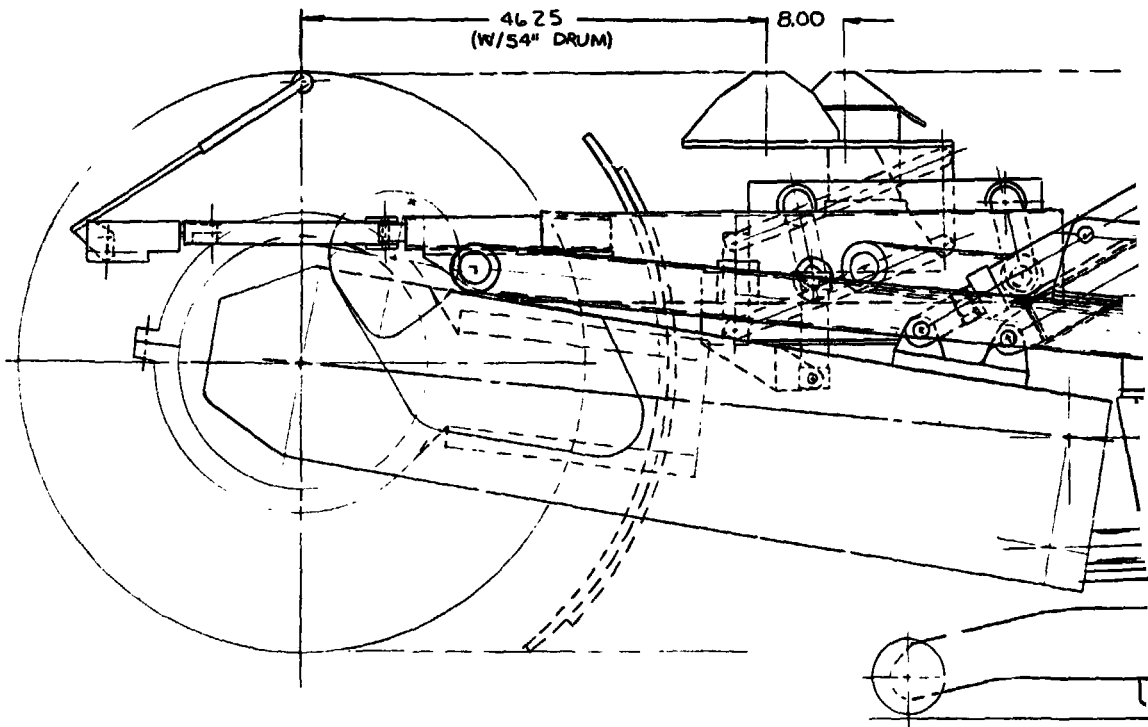
Figure 5-11.

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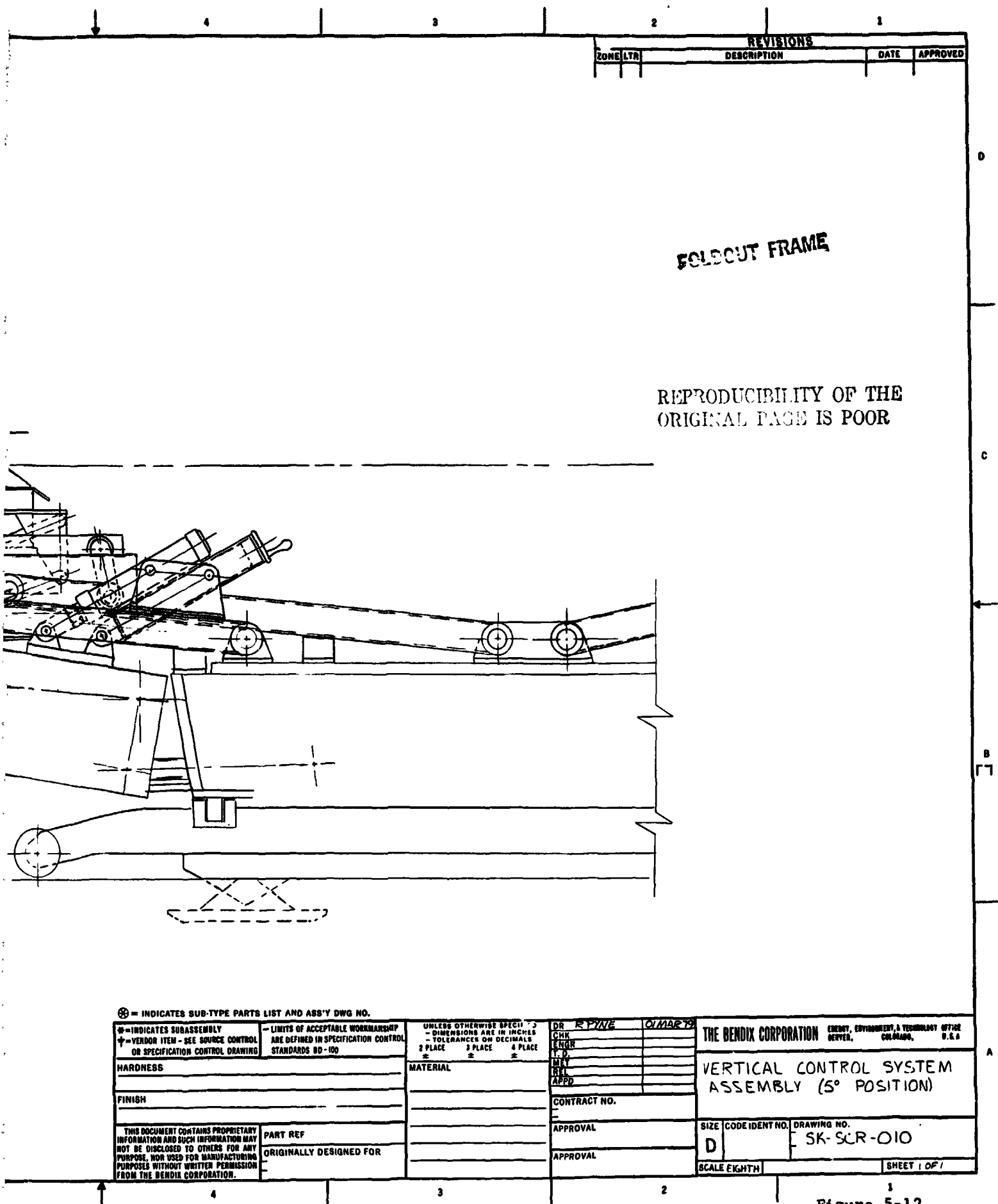
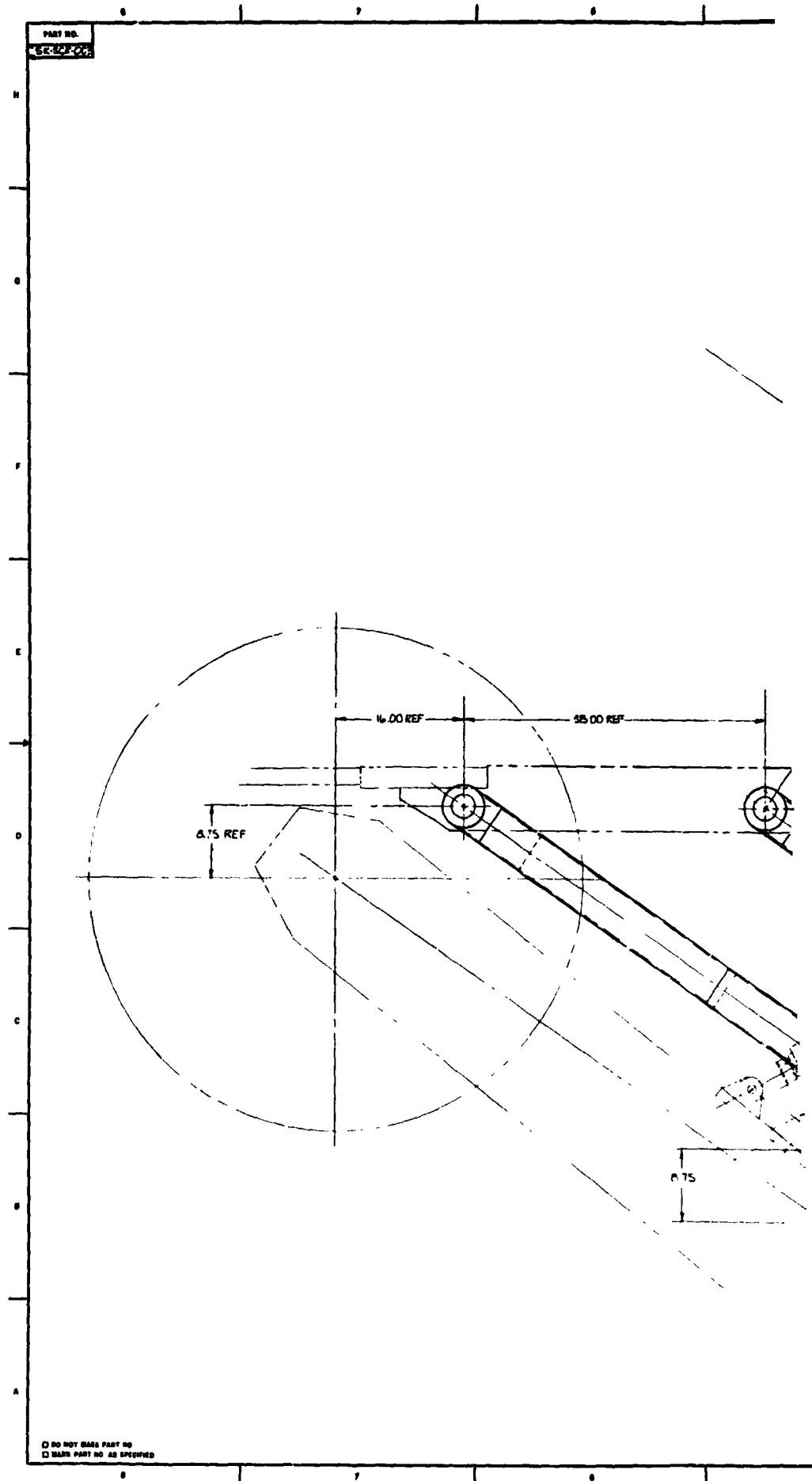


Figure 5-12.  
5-14

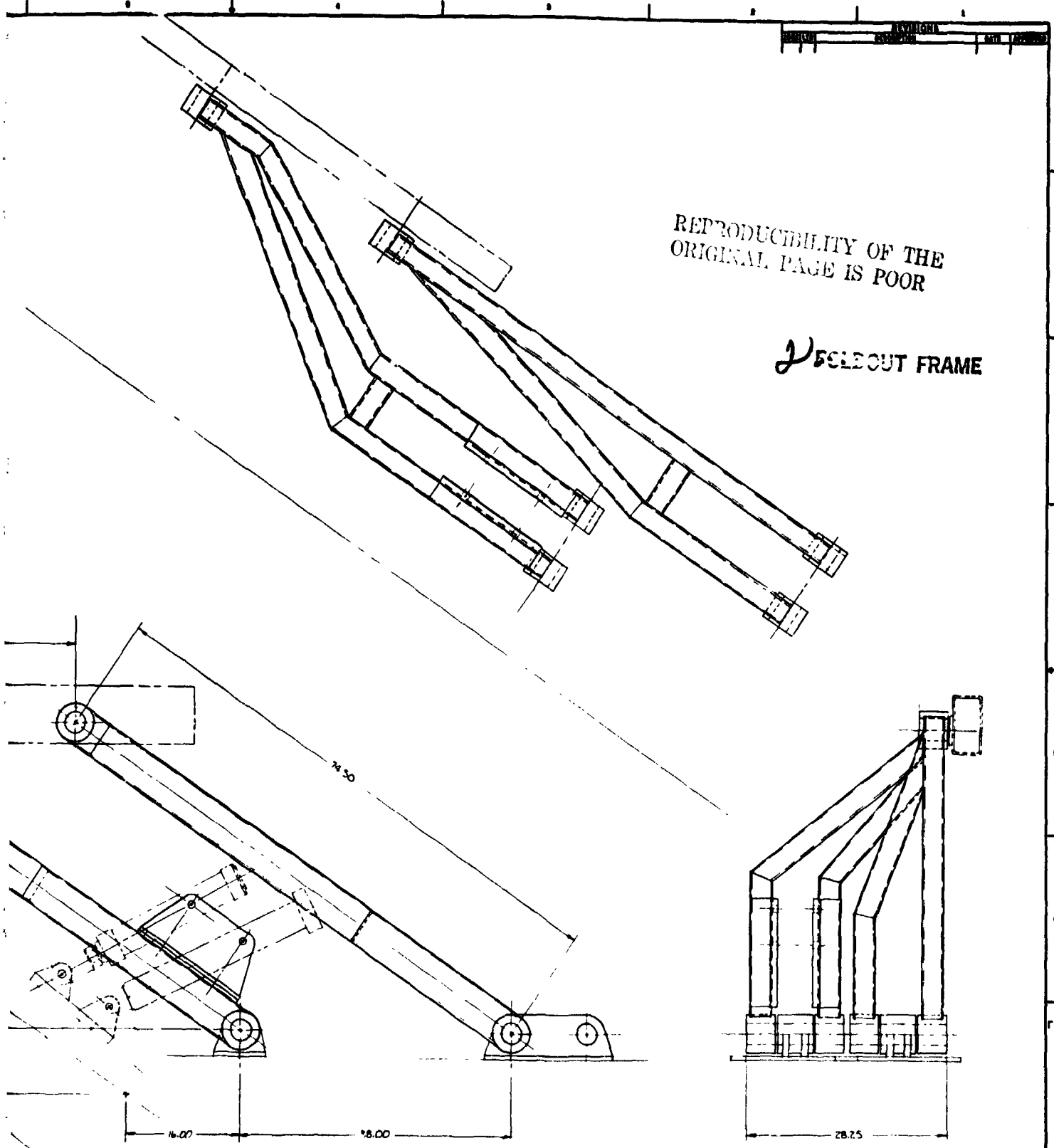
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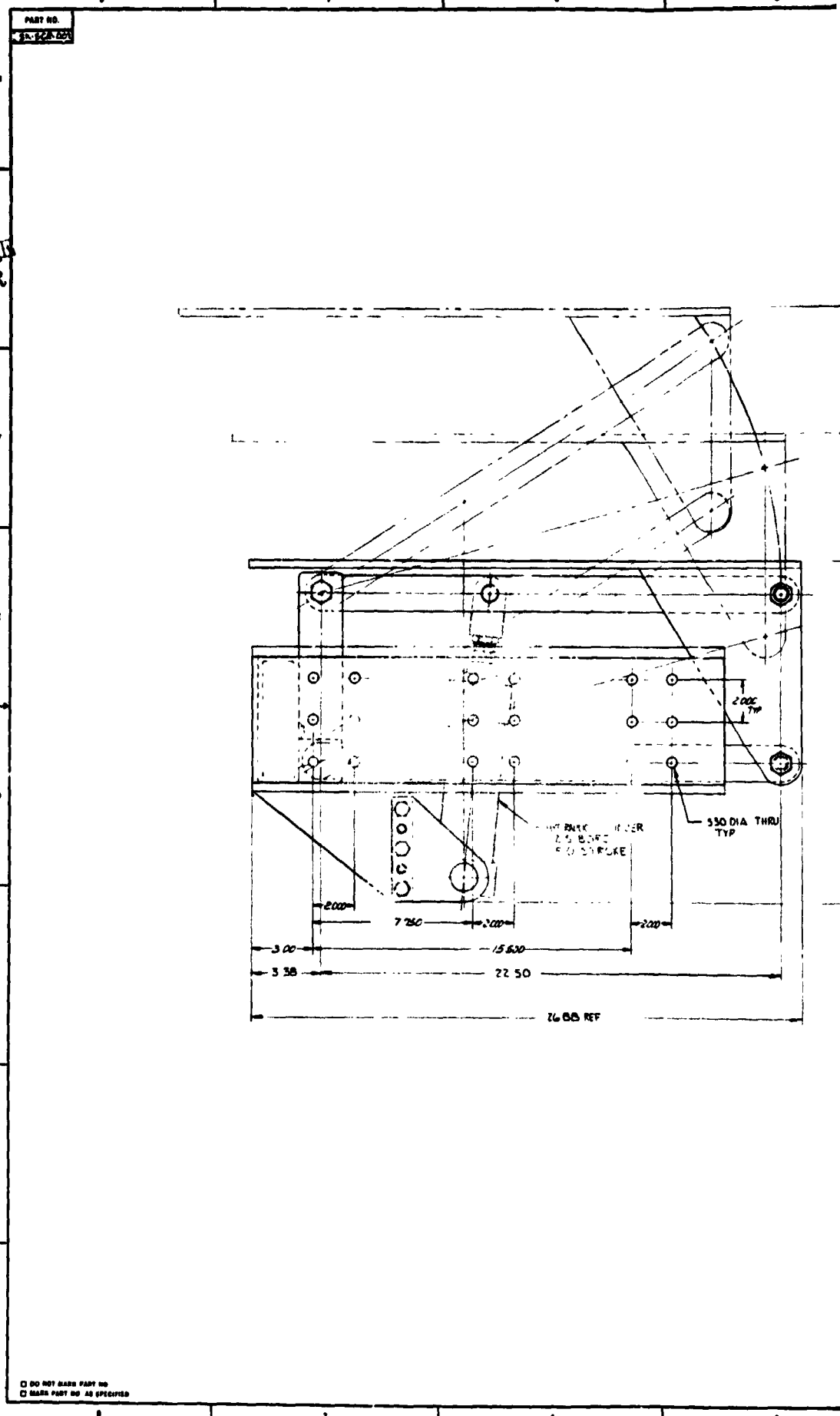
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Figure 5-13  
5-15

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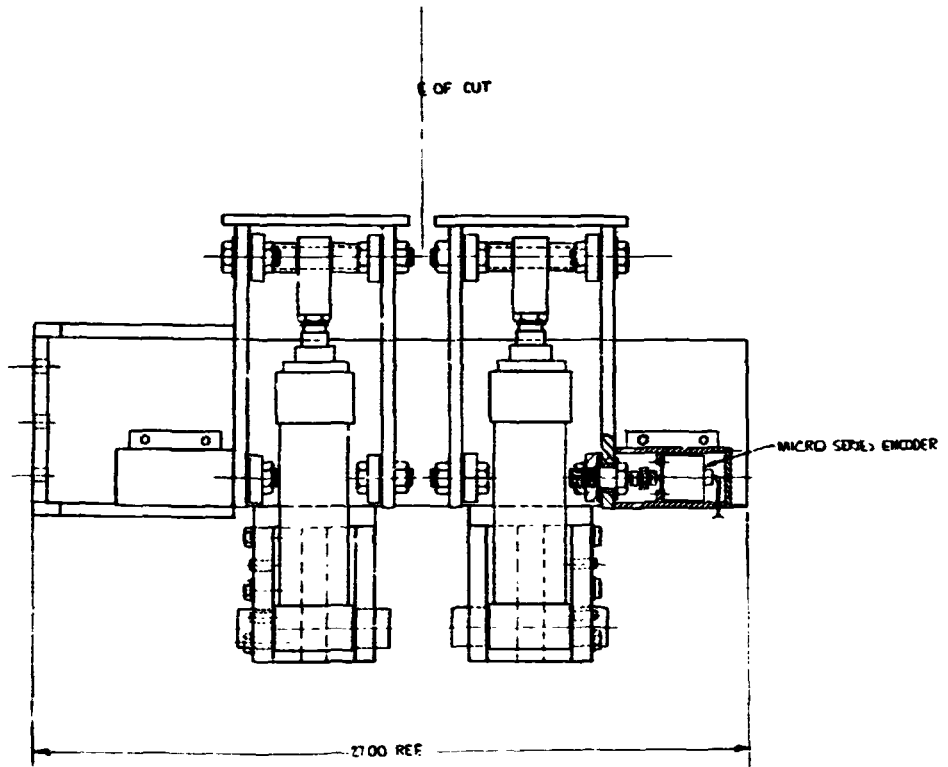
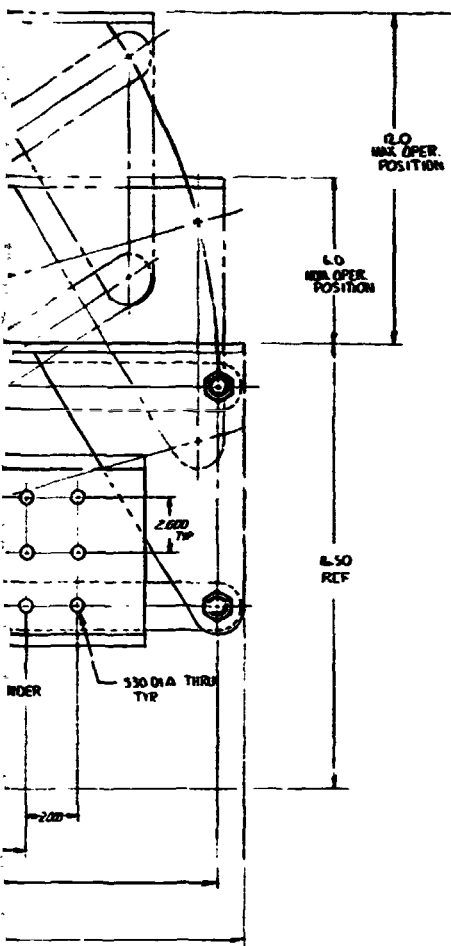
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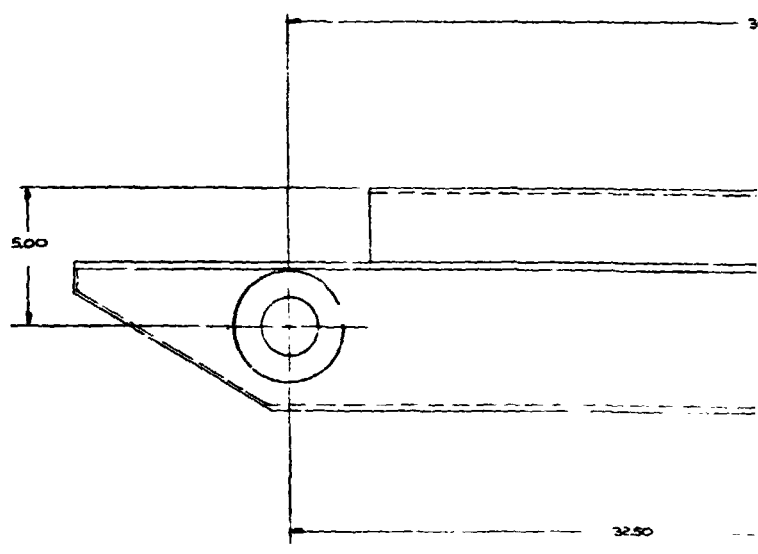
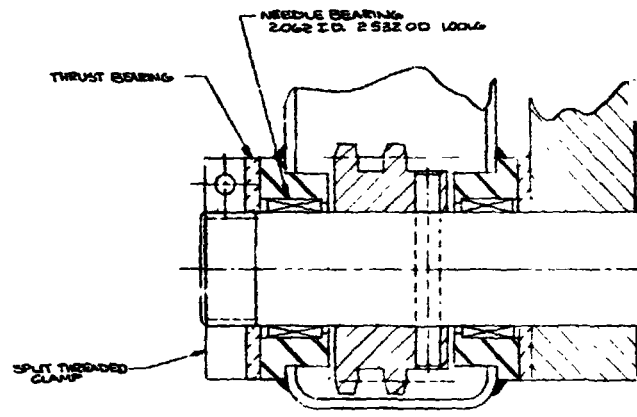
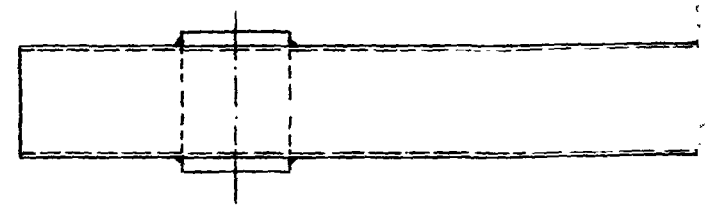
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Figure 5-14 .  
5-16

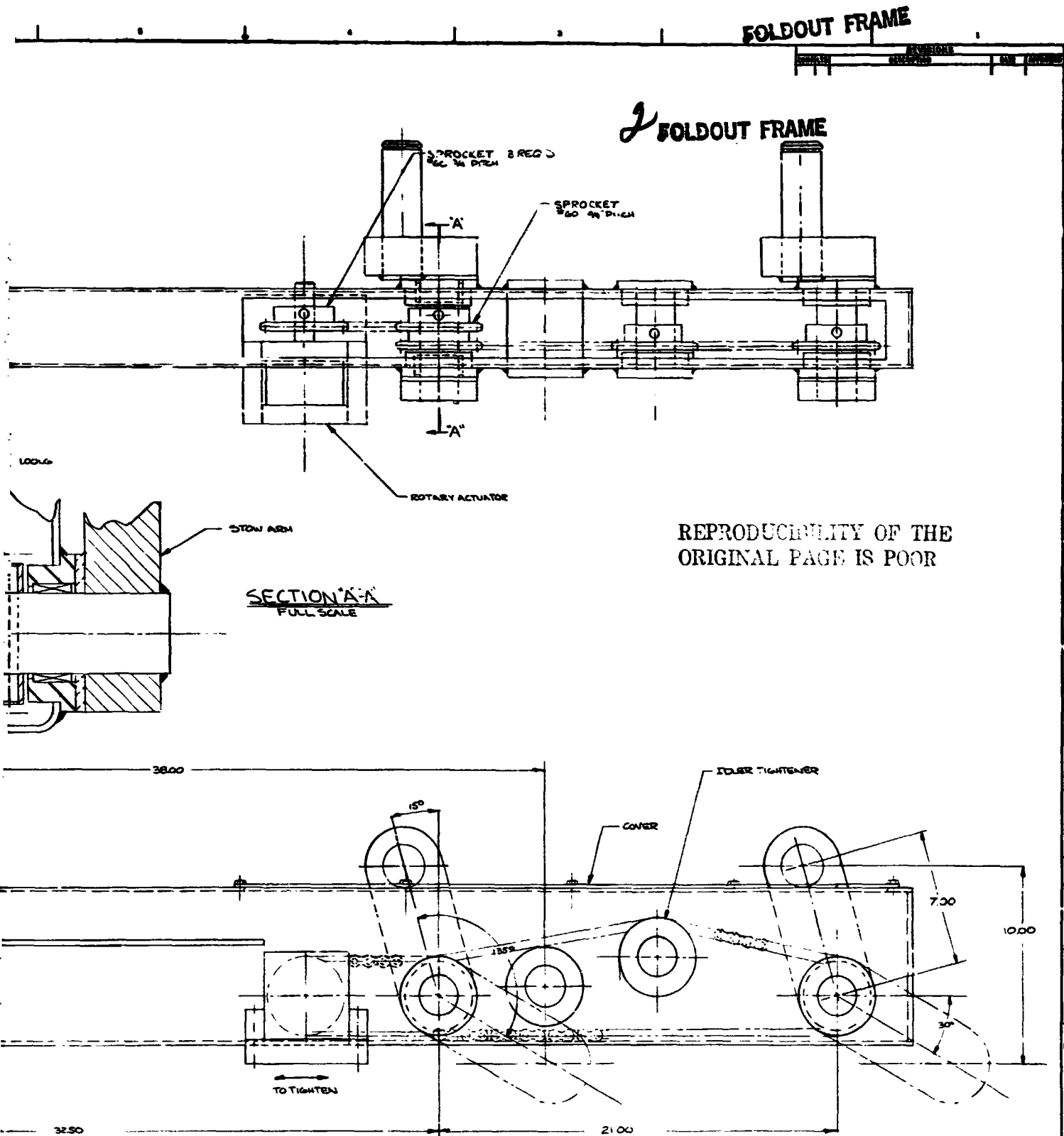
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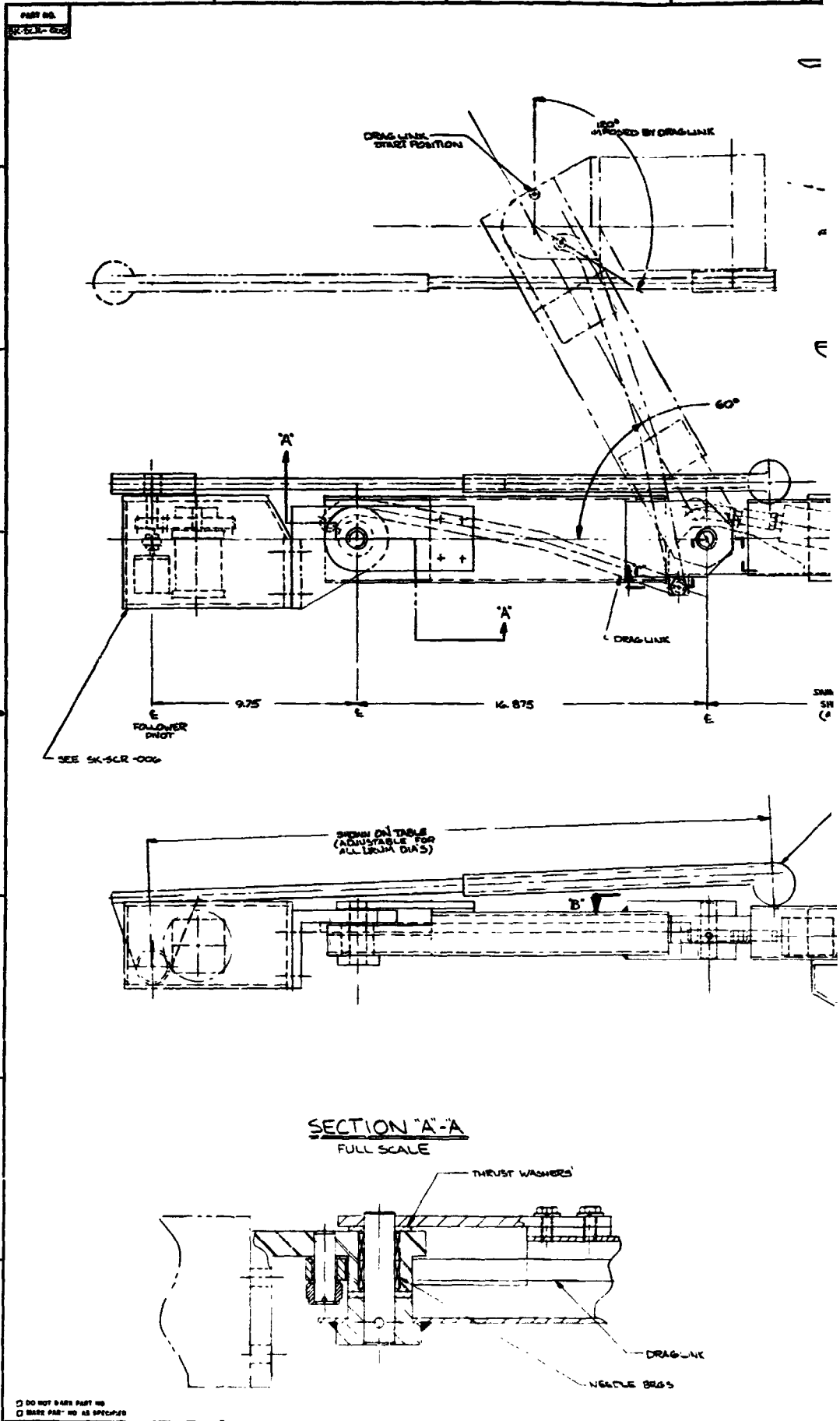


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Figure 5-15.  
5-17

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TERRAIGN

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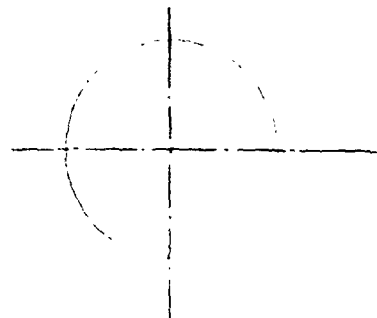
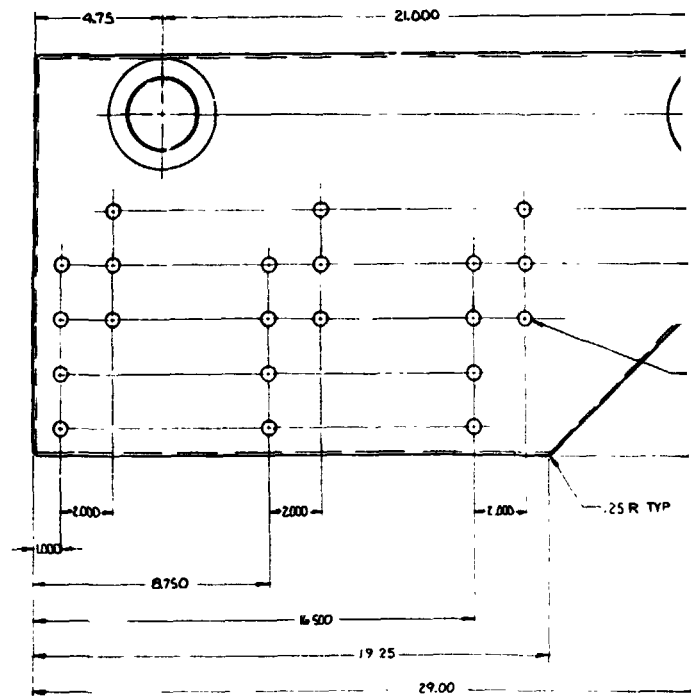
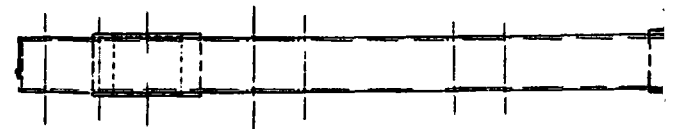
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Figure 5-17.

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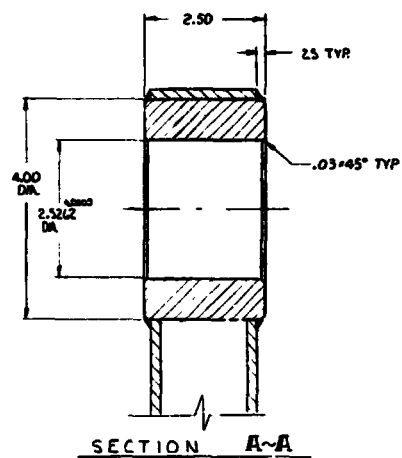
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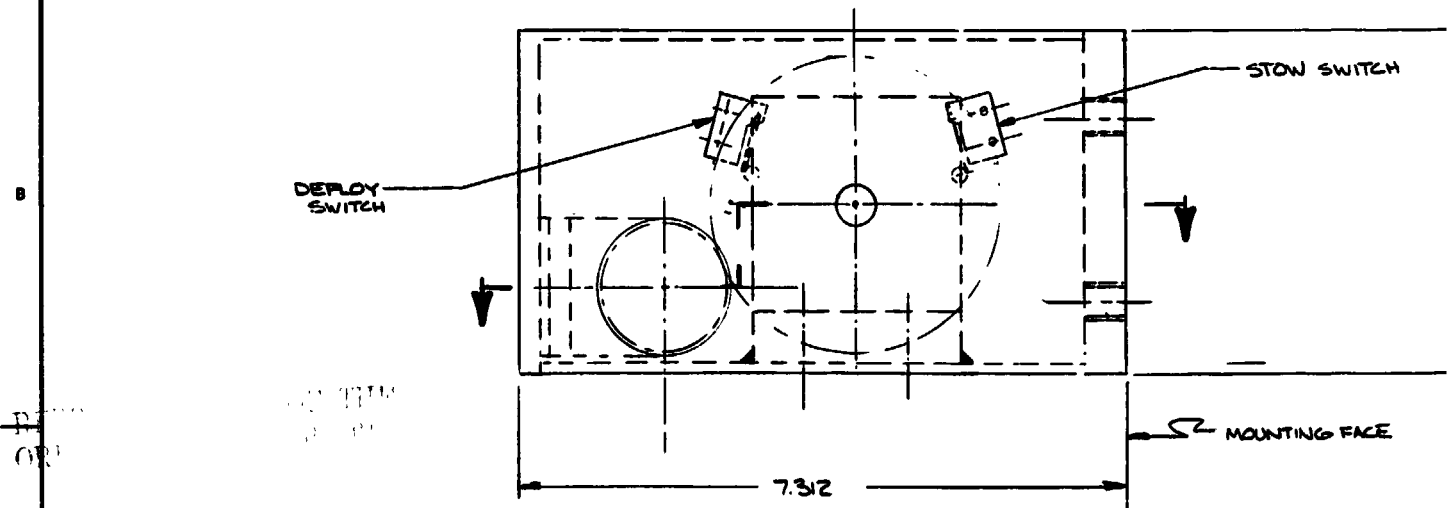
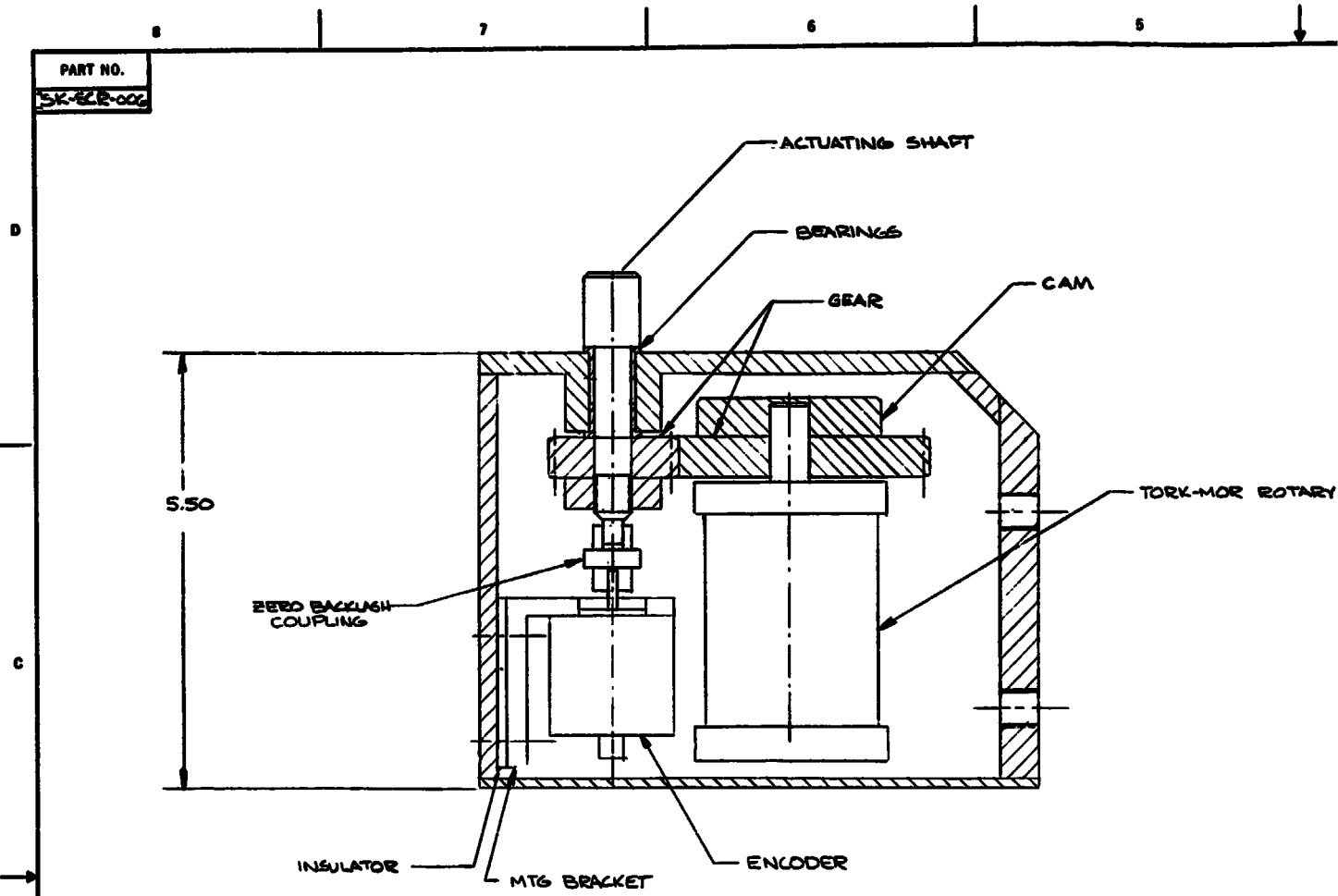


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Figure 5-18.  
5-20

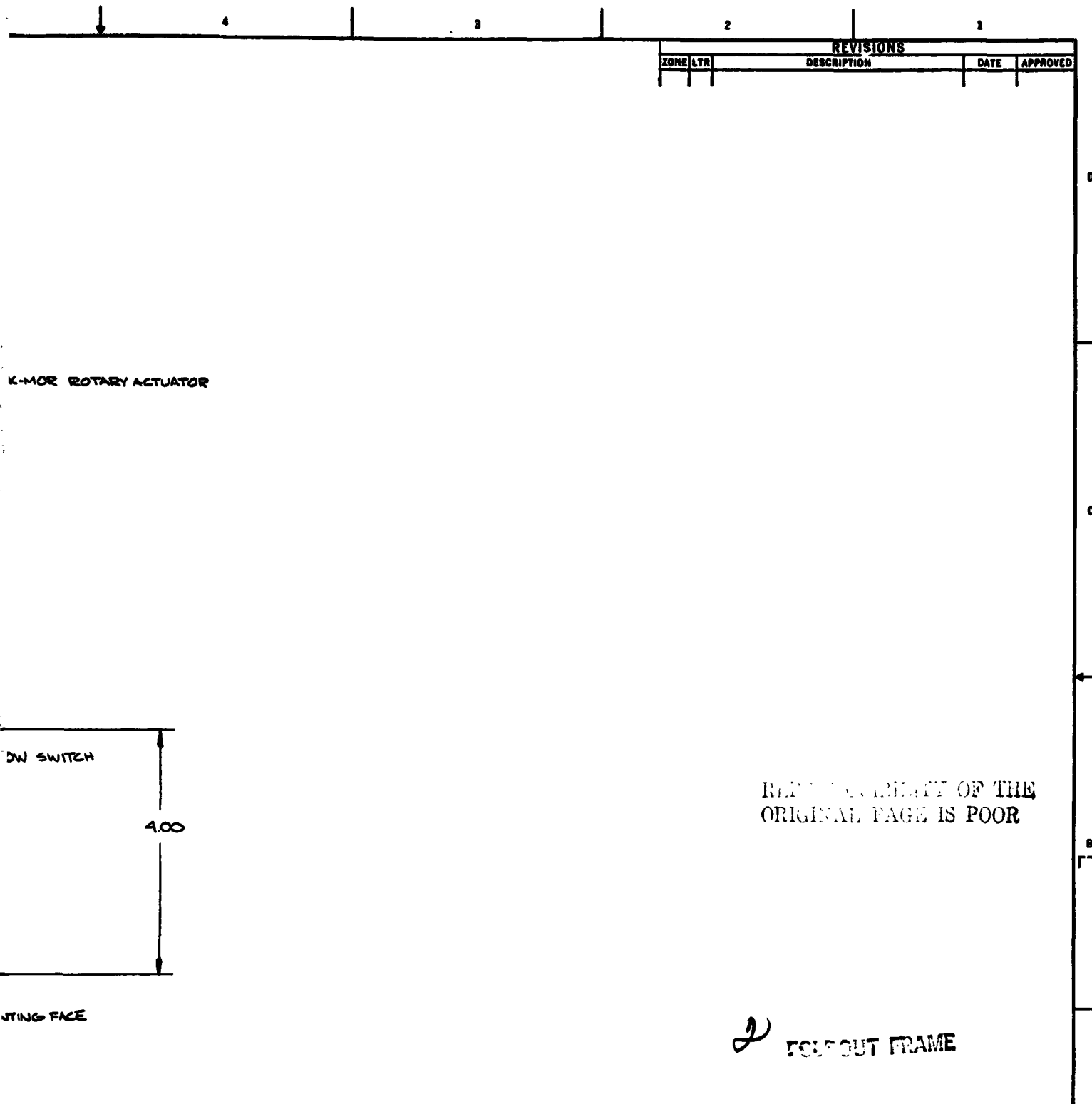
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Figure 19.  
5-21

PART NO

SOLITIZED PICK  
TRANSMITTER

DRUM ANGLE  
ENCODER

ENCODER  
SENSING HEAD  
DNG # SK-SCR-001

SWING ARM IN  
LAST CUT POSITION

COWL LIMIT  
SWITCH

49.35  
(W/54" URUM)

PASSIVE CID COVER  
DNG # SK-SCR-014

PASSIVE CID DEPLOYMENT  
MECHANISM DNG #

MOUNTING PLATE  
DNG # SK-84

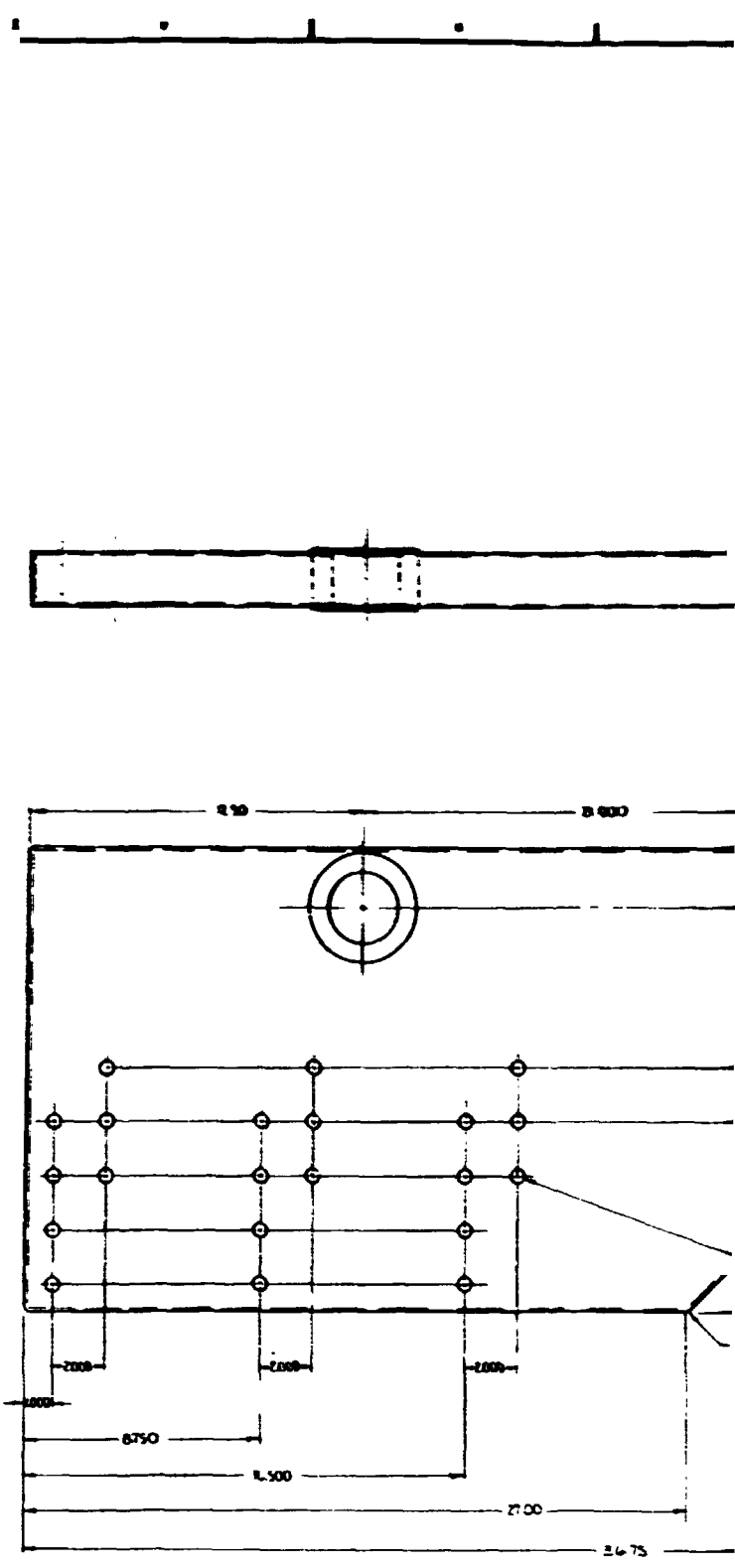
RANGING ARM  
LINEAR ENCODER

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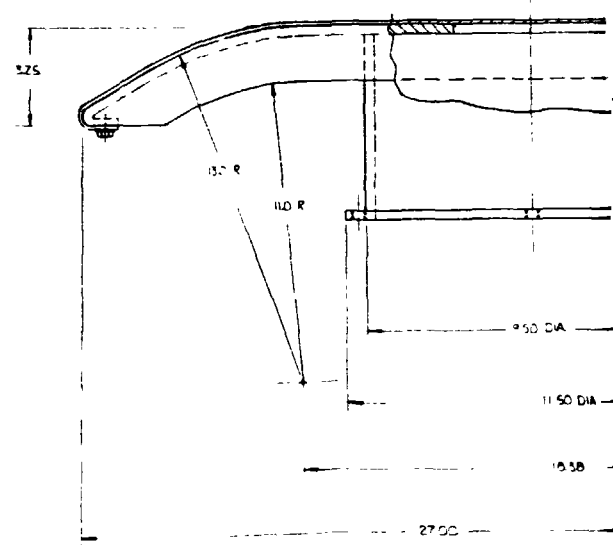
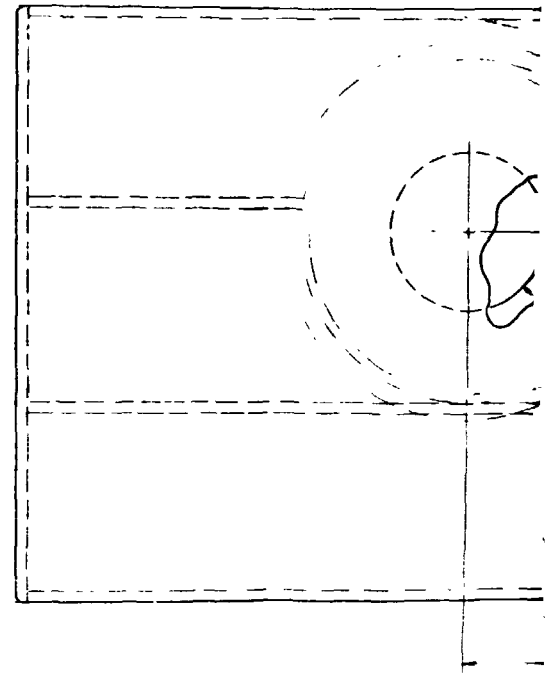


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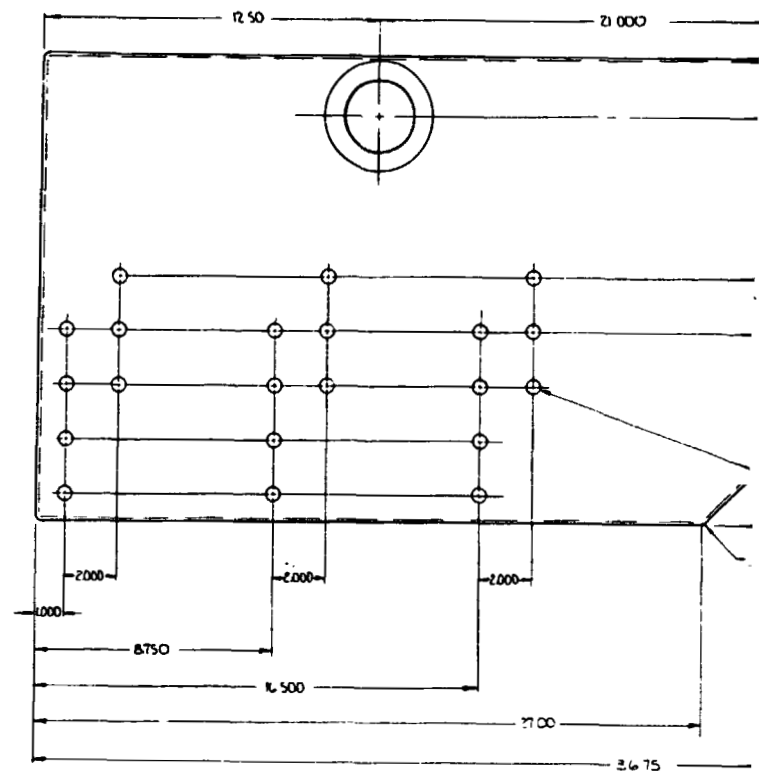
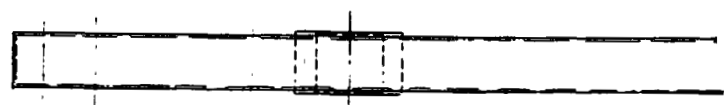


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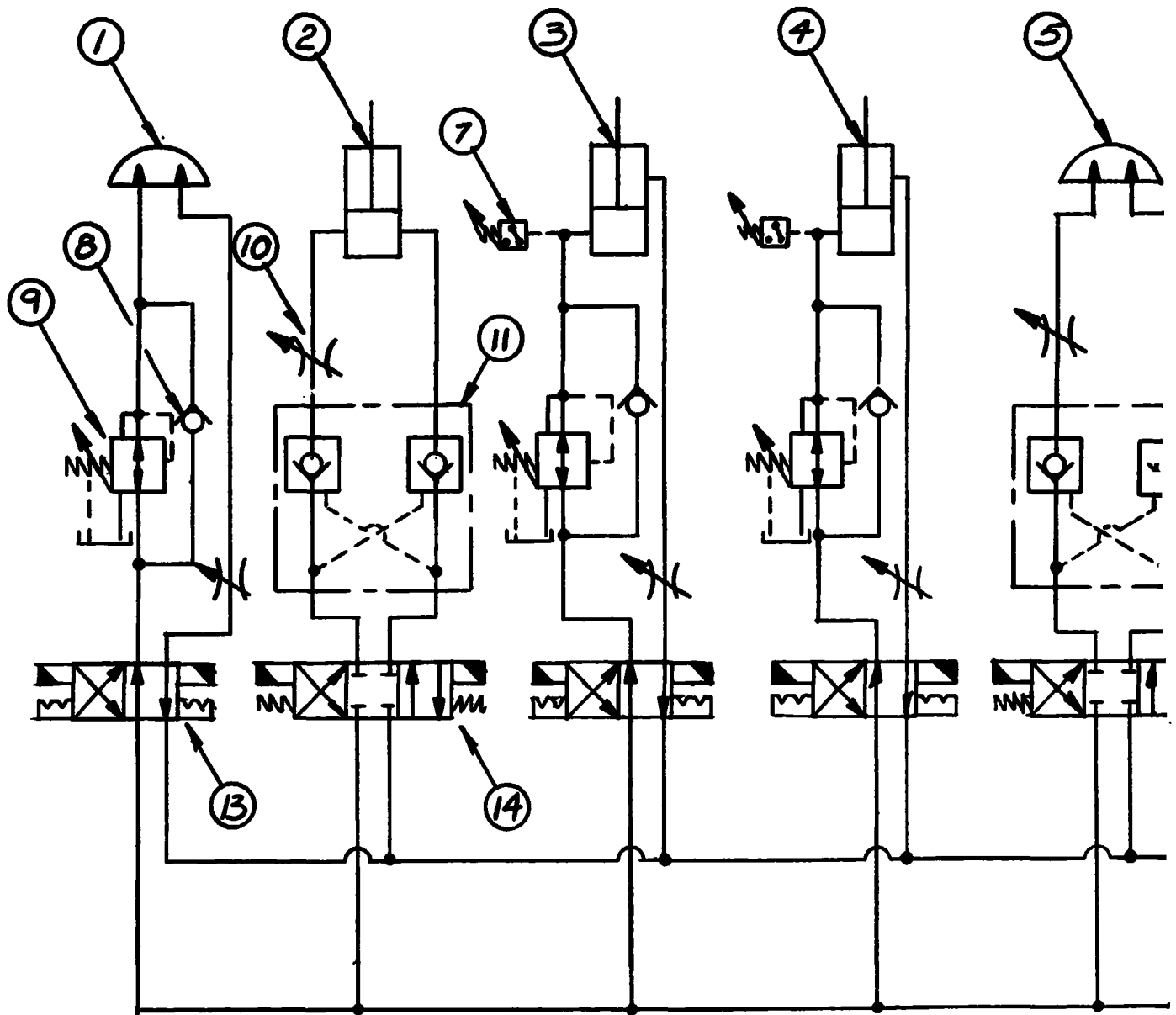


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□ TIME OF ACCEPTABLE WORKMANSHIP  
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 STANDARDS 80-100

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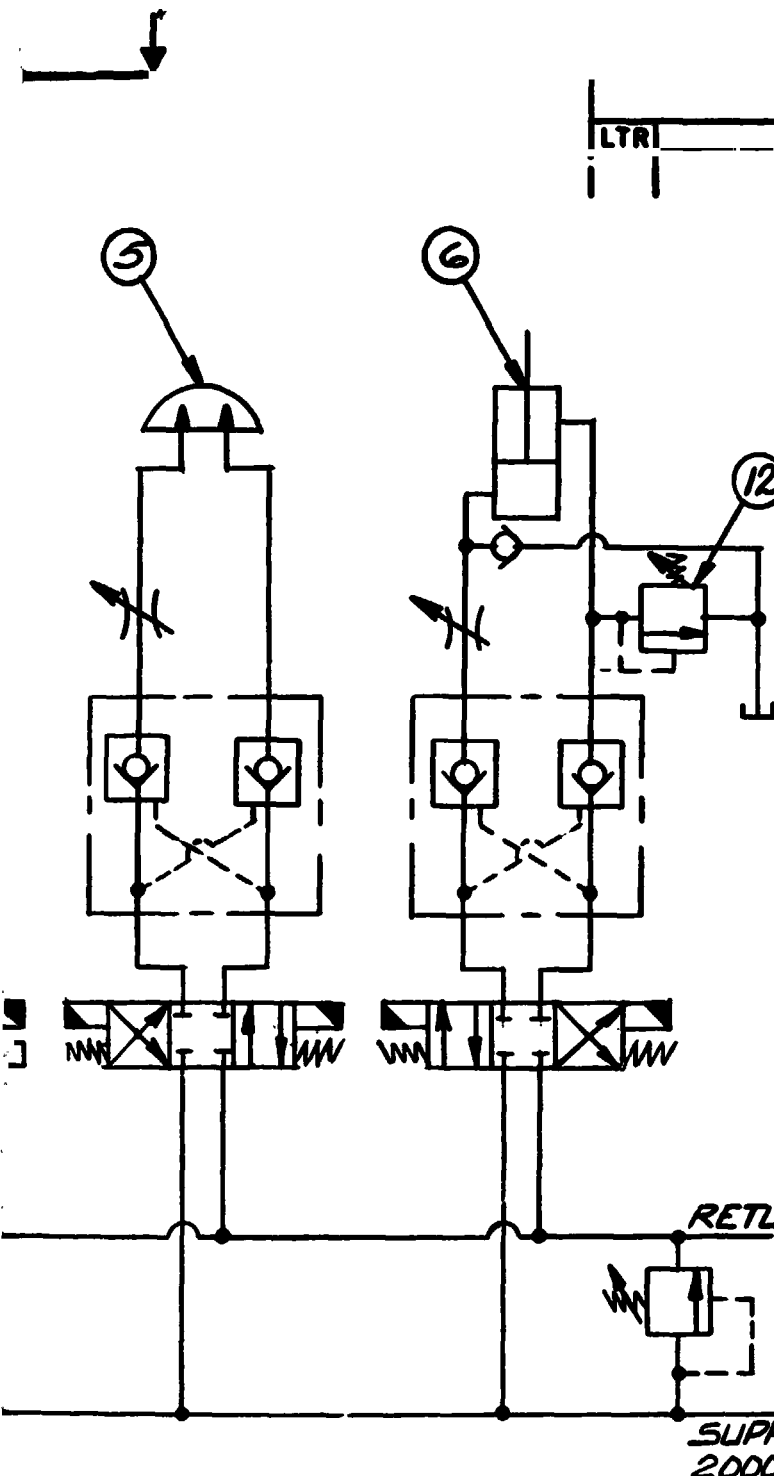
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MATERIAL







REVISIONS		
LTR	DESCRIPTION	DATE APPROVED

1. CUT FOLLOWER ROTARY ACTUATOR
2. SWING ARM CYL.
3. CID (SOURCE) DEPLOYMENT CYL.
4. CID (DETECTOR) DEPLOYMENT CYL.
5. CID STORAGE ROTARY ACTUATOR
6. SUPPORT CYLINDER
7. HYDRAULIC PRESSURE SWITCH
8. CHECK VALVE
9. PRESS. REDUCING VLV. W/BUILT-IN RELIEF
10. NEEDLE VALVE
11. DOUBLE PILOT CHECK VALVE
12. RELIEF VALVE
13. 4 WAY SOLENOID VALVE, 2 POSITION DETENTED
14. 4 WAY SOLENOID VALVE, SPRING CENTERED, CENTER PORTS BLOCKED

2  
SCOLDOUT FRAME

SUPPLY PRESSURE  
2000 PSI @ 6 GPM

UNLESS OTHERWISE SPECIFIED  
-DIMENSIONS ARE IN INCHES  
-TOLERANCES ON DECIMALS  
2 PLACE 3 PLACE 4 PLACE  
± ± ±  
MATERIAL

DR  
CHK  
T. D.  
MET.  
CONTRACT NO.

THE BENDIX CORPORATION ENERGY, ENVIRONMENT, & TECHNOLOGY OFFICE  
DENVER, COLORADO, U.S.A.

VCS HYDRAULIC  
SCHEMATIC

SIZE B CODE IDENT. NO DRAWING NO.  
B SK-SCR-016  
SPEC NONE SHEET 1 OF 1

Figure 5-24.  
5-26

Table 5-1. Table of Range and Adjustments

DRUM DIAMETER

	62"	58"	54"	50"	46"	42"
MAXIMUM SEAM HEIGHT	116"	108"	100"	92"	84"	76"
MINIMUM SEAM HEIGHT	72.75	70.75	68.75	66.75	64.75	62.75
RANGING ARM ANGLE OF OPERATION	45.5°	42.5°	36.6°	33.2°	29.8°	20°
CUT FOLLOWER LENGTH	30.5	28.25	24.75	24.00	20.00	17.00
SWING ARM SHIFT	9.61	7.37	5.21	3.80	2.27	0
CENTER LINE OF DRUM TO PASSIVE CID CENTER LINE	53.38	51.38	49.38	48.13	46.13	44.13
CENTER LINE OF DRUM TO CENTER LINE OF ACTIVE CID UNITS	54.25	52.25	50.25	49.00	47.00	45.00

When the support parallelogram is used in the trailing drum mode, the support cylinder is extended against the adjustable screw stop, Figure 5-17. This screw stop is manually adjustable for seam height. In this position, the horizontal support still follows the drum, though not proportionally, enabling the PCF to be used.

The L/PCF is mounted to the horizontal support. Two adjustments are required for different drum diameters: the swing arm assembly telescopes in the horizontal support and the cut follower arm telescopes on itself.

The cut follower arm is loaded against the roof and retracted by a hydraulic rotary actuator located in the encoding head part of the swing arm assembly (see Figure 5-19). Height is sensed by an angular encoder attached to the shaft. The circuitry of the actuator includes an adjustable pressure regulating relief valve which allows the cut follower to follow contours on the roof and still maintain constant pressure.

The swing arm on the forward cutting drum is shown in the LCF position. To shift to PCF position, the swing arm cylinder retracts, rotating the swing arm  $60^{\circ}$ . A drag link, Figure 5-16, located inside the swing arm, rotates the encoding head thru  $120^{\circ}$ ,  $180^{\circ}$  relative to the LCF position. In this position, the cut follower is again at an angle which allows it to collapse away from an obstruction when the machine is going in the other direction. A solid ball follower has replaced the wheel used in earlier designs.

The CID deployment mechanism, Figure 5-14, is attached to the horizontal support by the CID stowage mechanism, shown in Figure 5-15. Adjustment for the 54" to 62" drum sizes is achieved by selecting the correct bolt pattern between the CID mounting plate, shown in Figure 5-18, and the CID deployment mechanism. The CID mounting plate is attached to two shafts on the stowage mechanism which can be rotated into the forward position to enable the same mounting plate to be used for 42" to 50" drum size adjustment. The stowage mechanism shown in Figure 5-15 is chain driven by a rotary actuator, which rotates the CID package to its stow position as shown on the trailing drum end of the machine in Figure 5-11.

The source and detector are independently suspended with a set of parallelogram bars allowing  $\pm 6"$  of travel. This arrangement allows the mechanism to collapse down as it is forced back by an obstruction. A CID deployment cylinder for each unit retracts or loads them against the roof. Adjustable pressure regulating relief valves in the hydraulic circuit allow the CID units to follow contours on the roof while maintaining constant pressure. Angular encoders, shown on Figure 5-14, sense height variation.

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The hydraulic circuit, shown in Figure 5-24, is designed in such a way that loss of hydraulic pressure will freeze all mechanisms in place. They may be manually stowed by loosening the hydraulic fittings. Hydraulic damping is provided by adjustable needle valves to prevent the various mechanisms from banging against their stops or the roof. In particular, this will prevent damage to the CID and cut followers that might otherwise occur from striking the roof after clearing an obstruction.

5.3 Sequence of Operation - When the mechanism is in the leading drum position; the sequence required to convert to trailing drum position is:

1. Stow cut follower (Rotary Actuator)
2. Retract CID deployment cylinders
3. Retract CID stowage mechanism (Rotary Actuator)
4. Lower ranging arm
5. Extend support cylinder
6. Set cowl position
7. Retract swing arm cylinder (into PCF position)
8. Deploy cut follower (Rotary Actuator)

At the same time the opposite mechanism will convert to leading drum position in the following sequence.

1. Stow cut follower (Rotary Actuator)
2. Extend swing arm cylinder (into LCF position)
3. Set cowl position
4. Retract support cylinder
5. Raise ranging arm
6. Deploy cut follower (Rotary Actuator)
7. Extend CID stowage mechanism (Rotary Actuator)
8. Extend CID deployment cylinders

The manual mode position is defined as:

1. CID deployment cylinders retracted
2. CID stowed
3. Swing arm in LCF position
4. Cut follower stowed

5.4 Modification Required to Substitute Passive CID - The passive CID, Figures 5-20 thru 5-23, operates similarly to the active CID. To interchange CID's, when using a 54" to 62" drum, one is simply unbolted and the other bolted to the same CID mounting plate. A separate CID mounting plate and shorter stow arms as shown in Figure 5-23 must be used for the 42" to 50" drum sizes. This adaption hardware is easily substituted for the mounting plate and stow arms used for the 54" to 62" size drums making the design for the passive radiation CID compatible with all drum sizes available for the Joy 300-1LS1 longwall shearer.

The CID is loaded against the roof by a hydraulic cylinder operating in a vertical track, see Figure 5-21. Height is measured with a linear encoder located along the track. Sliding contact was chosen to reduce complexity and to insure self-cleaning of the detector crystal surface. A sheet of 15 ga. (1/16") spring steel is used as a wear surface and cover for the detection crystal. This thickness will cause minimal interference to the CID. Since air gaps are not a problem on the passive sensor, pressure against the roof can be light, reducing wear on the replaceable sliding surface.

In this configuration, with the passive CID, the stowage mechanism is used as a swing away protection device as well as for stowage. The lip on the CID cover, Figure 5-22, will enable the CID to clear small obstructions by collapsing vertically. If a larger obstruction is encountered with sufficient force to overcome the pressure in the stowage rotary actuator, the stow arm will rotate, allowing the CID deployment mechanism to fold back. As soon as the stow arms begin to rotate the deployment cylinder will be retracted. After the obstruction has cleared and the stow arms are able to return to their upright position, the deployment cylinder will extend, again loading the CID against the roof.